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FINE PARTICULATE EMISSION INVENTORY AND CONTROL SURVEY

Midwest Research Institute

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January 1974

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16. ABSTRACT

An emission inventory for fine particulates was developed for National Air Data Branch. Attention was focused on estimates of primary particulates, and not on secondary particulates formed by subsequent reaction of source emissions in the atmosphere. Both stationary point and area sources of fine particulates were included in the emission inventory for fine particles. The contribution of mobile sources to the primary fine particulate burden was also included in order to place the problem in perspective.

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January 1974

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Approved for:

MIDWEST RESEARCH INSTITUTE

H. M. Hubbard, Director
Physical Sciences Division

SUMMARY

An emission inventory for fine particulates was developed for the National Air Data Branch, Office of Air Quality Planning and Standards as Task No. 1 on Contract No. 68-02-1324. The program was divided into six major areas of activity: (1) an information search to determine the availability of data and other background information necessary to define fine particle emissions; (2) preparation of an inventory of estimated fine particulate emissions in the United States; (3) compilation of information on the chemical and physical properties of fine particulate emissions; (4) development of methodology to perform a detailed emission inventory of fine particulates for the entire United States and for four cities in the U.S. identified as having a possible fine particulate problem through the use of EPA's National Emission Data System; (5) assessment and overview of the current status of emission inventories for fine particulates; and (6) recommendations for future work.

INFORMATION ACQUISITION

Acquisition of data relating to fine particulate emissions from various sources was an integral part of the program. To estimate the emissions of fine particulates from various sources, data for the production, distance traveled, area burned, etc., mass emission factors, fractional efficiency of control equipment, extent of control, and particle size distributions of emitted particulates must be known for each emission source. MRI had compiled an extensive data base as a result of the initial emission inventory of fine particulates which we performed as a part of our effort for EPA on Contract No. CPA-22-69-104 (Particulate Pollutant System Study). Efforts on information acquisition during the present program were directed to updating the existing data base.

Contacts were made with various EPA personnel, control equipment manufacturers, selected state air pollution control agencies, and several companies involved in source testing programs. Only a limited amount of new data on particle size distributions of emitted particulates and fractional efficiency characteristics of control equipment were obtained from these contacts. In general, neither control equipment manufacturers nor air pollution control agencies have yet placed any significant emphasis on the particle size of material emitted from sources or control equipment. At the present time, the major efforts to enlarge the data base on particle size distributions and fractional efficiency of control equipment are being exerted by segments of EPA.

FINE PARTICULATE EMISSIONS (1971-1972)

Estimates of fine particle emissions* were made for three categories of sources: stationary point, stationary area and mobile. Attention was focused only on primary particulates and no attempt was made to estimate secondary particulates formed by subsequent reaction of source emissions in the atmosphere. Emphasis was placed on stationary point and area sources and the mobile sources were included to provide prospective to the problem of fine particle emissions. The procedures used to calculate fine particle emissions in each source category are discussed on pages 20 to 23.

Stationary Point Sources

Tables 1 and 2 summarize the estimates of fine particle emissions from stationary point sources. The emission totals in Tables 1 and 2 are based on 1972 production data. Table 1 presents fine particle emissions from industrial sources for which sufficient data are available to permit detailed estimates in discrete particle size ranges. Two "total" columns are presented in Table 1--the first including the 0.1-3 micron size range and the second the 0.01-7 micron range. The former column is presented to facilitate comparison with our previous emission inventory for fine particles. Fine particle emissions from some industrial sources could not be estimated in discrete particle size ranges because of incomplete particle size distribution data, and Table 2 presents gross estimates of fine particle emissions from sources for which this was the case. The emission totals in Table 2 are estimates of the total quantity of particulates less than 7 microns in diameter emitted from the specific industrial source categories.

---

* There is no universally acceptable definition of fine particulates. In this study, we chose an upper cut-off point of 7-micron diameter. In our previous emission inventory of fine particles, an upper cut-off point of 3-micron diameter was employed.

Table 1. FINE PARTICLE EMISSIONS FROM SELECTED INDUSTRIAL SOURCES
(mass basis, 10^3 tons/year)

	Fine Particle Size Ranges (microns)						Total	
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	0.01-3	0.01-7
1. Hot-mix asphalt plants								
A. Rotary dryer	36.1	139.0	51.4	27.4	0.5		218.3	254.4
B. Vent line	11.0	19.5	2.4	0.4			22.3	33.3
Total from hot-mix asphalt plants							240.6	287.7
2. Cement plants, rotary kilns	102.5	101.7	24.4	11.7	0.3		138.1	240.6
Total from cement plants							138.1	240.6
3. Ferroalloys								
A. Electric furnace								
1. Ferrosilicon alloys	1.9	19.0	28.7	83.6	17.9	8.2	157.4	159.3
2. Ferromanganese alloys	3.2	15.8	9.6	4.6			30.0	33.2
3. Ferrochromium alloys	11.0	22.8	14.5	18.9	2.0	0.8	59.0	70.0
4. Miscellaneous ferro-alloys	3.8	12.0	9.4	13.0	1.1	0.4	35.9	39.7
Total from ferroalloys							282.3	302.2
4. Fertilizers, granulators and dryers	5.3	8.7	3.8	3.3	0.4		16.2	21.5
Total from fertilizer plants							16.2	21.5
5. Iron and steel								
A. Basic oxygen furnaces		1.8	39.3	318.4	2.1		361.6	361.6
B. Electric arc furnaces	3.1	5.1	3.4	6.9	2.2	2.6	20.2	23.3
C. Open hearth furnaces	0.7	6.8	18.4	63.6	7.2	1.3	97.3	98.0
D. Sinter machines	3.7	3.7	1.2	0.6			5.5	9.2
Total from iron and steel							484.6	492.1
6. Iron foundries, cupolas	6.1	6.5	2.5	3.3	0.5	0.6	13.4	19.5
Total from iron foundries							13.4	19.5
7. Kraft pulp mills								
A. Bark fired boilers	59.3	58.8	14.7	7.3	0.3	0.1	81.5	140.5
B. Recovery furnaces	28.0	123.2	100.8	96.6	1.9	0.1	322.6	350.6
C. Lime kilns	1.2	2.1	0.3	0.1			2.5	3.7
Total from kraft pulp mills							406.6	494.8
8. Lime plants								
A. Rotary kilns	27.8	39.6	19.1	24.7	3.2	2.2	88.8	116.6
B. Secondary sources	24.0	44.6	8.5	1.4			54.5	78.5
Total from lime plants							143.3	195.1
9. Municipal incinerators	4.6	9.1	5.6	8.6	2.1	3.2	28.6	33.2
Total from municipal incinerators							28.6	33.2
10. Stationary combustion								
A. Coal								
1. Electric utility								
a. Pulverized	665.8	659.4	199.4	111.0	3.1		972.9	1,638.7
b. Stoker	57.3	23.3	5.9	2.1			31.3	88.6
c. Cyclone	53.1	53.8	15.7	8.1	0.2		77.8	130.9
Subtotal from electric utility coal							1,082.0	1,858.2

Table 1. (Concluded)

Source	Fine Particle Size Ranges (microns) 3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total 0.01-3	Total 0.01-7
10. Stationary combustion (concluded)								
2. Industrial								
a. Pulverized	69.0	22.1	0.8				22.9	91.9
b. Stoker	193.0	84.5	10.9	3.1			98.5	291.5
c. Cyclone	11.8	20.0	10.0	6.1	0.3	0.1	36.5	48.3
				Subtotal from industrial coal			157.9	431.7
B. Fuel oil								
1. Electric utility and industrial	190.7						190.7	190.7
				Subtotal from fuel oil			190.7	190.7
C. Natural Gas and LPG								
1. Electric utility and industrial		104.9					104.9	104.9
				Subtotal from gas			104.9	104.9
				Total from fuel combustion			1,535.5	2,685.5
				Total major industrial sources			3,289.2	4,672.2

Table 2. GROSS ESTIMATES OF FINE PARTICLE EMISSIONS FROM SELECTED INDUSTRIAL SOURCE CATEGORIES

Industrial Source Category	Fine Particle Emissions[a] (10^3 tons/year)
Crushed stone	868
Secondary nonferrous metallurgy	127
Petroleum FCC units	50
Coal preparation plants, thermal dryers	42
Carbon black	39
Acid plants	
(a) Sulfuric	2.8
(b) Phosphoric (thermal)	1.2
	1,130.0

---

[a] Estimated particulate emissions less than 7 μ in diameter.

Emissions of particles in the size range 0.01-3 microns from the industrial sources listed in Table 1 are estimated at 3.3 x 10^6 tons/year while those in the size range 0.01-7 microns are estimated at 4.7 x 10^6 tons/year. Adding the gross estimates of Table 2, estimated emissions range from 4.4 x 10^6 (for 0.01-3 microns) to 5.8 x 10^6 tons/year (0.01-7 microns). In view of the many assumptions involved in the estimates, the individual emission quantities shown in Tables 1 and 2 are considered to be a "first-cut" estimate. Because of the inadequacies of the sampling and particle sizing techniques used to obtain much of the data on particle size distributions and control equipment fractional efficiency, uncontrolled fine particle emissions from specific sources are probably higher and the fractional efficiency of many control devices lower than those values used to prepare the estimates shown in Tables 1 and 2.

In addition, calculations of fine particle emissions from controlled sources were based on the assumption that control equipment is in operation 100% of the time that a source is operating. This is seldom the case, but data are generally not available on control equipment operational availability. Therefore, fine particle emissions from the sources are likely to be greater than the estimates shown in Tables 1 and 2, and the totals shown in Tables 1 and 2 are considered to be conservative estimates of fine particle emissions. The extent of the conservatism can not be readily assessed.

Furthermore, fine particle emissions from primary nonferrous metallurgy and many mineral processing operations could not be estimated because of a totally inadequate data base for those source categories.

Stationary Area Sources

Wildfires, prescribed burning, agricultural burning, structural fires, burning coal refuse banks and fugitive dust sources such as unpaved roads and airstrips, construction sites, agricultural tillage, and aggregate storage piles were included in the category of stationary area sources for the purposes of this inventory. It was not possible to make estimates of the fine particle emissions from the fugitive dust sources because of lack of data on source strengths (i.e., vehicle miles travelled, acres tilled, number and type of aggregate storage piles). Information on emission factors for the fugitive dust sources is presented on pages 53 to 57.

Estimates of fine particle emissions from selected stationary area sources are presented in Table 3. Specific details of the calculations for each source category are presented on pages 46 to 53. The emission figures shown in Table 3 are based on 1971 estimates of fuel, acreage, or incidences of

Table 3. ESTIMATED FINE PARTICLE EMISSIONS FROM SELECTED STATIONARY AREA SOURCES

Area Source	Fine Particle Emissions (tons/year)						Total	
	3-7 μ	1-3 μ	0.5-1.0 μ	0.1-0.5 μ	0.05-0.1 μ	0.01-0.05 μ	0.01-3 μ	0.01-7 μ
Wildfires (forest fires)				496,047	1,229,334	431,346	2,156,728	2,156,728
Prescribed burning				41,016	101,648	35,666	178,330	178,330
Agricultural burning	4,216	19,584	32,640	127,840	39,440	43,520	263,024	267,240
Structural fires				13,294	32,946	11,560	57,800	57,800
Burning coal refuse banks	114,750						114,750	114,750

occurrence. Estimated emissions of fine particulates from the sources delineated in Table 3 are 2.8 x 10^6 tons/year. The contributions of sources such as forest fires may go up or down from year to year depending upon the severity of a given fire year and variations of climatic conditions.

Mobile Sources

Mobile sources were assumed to be uncontrolled sources of particulate pollutants. Estimates of fine particle emissions from mobile sources in 1971 are presented in Table 4. An estimated total of 1.01 x 10^6 tons/year of fine particulates was emitted from mobile sources in 1971.

Comparison of Emissions from Stationary Point, Stationary Area and Mobile Sources

Table 5 presents a comparison of particulate emissions in the size range 0.01-7 microns from the stationary point, stationary area, and mobile sources for which sufficient data were available to perform the estimates. Stationary point sources account for slightly more than 60% of the emissions.

CHEMICAL AND PHYSICAL CHARACTERISTICS OF FINE PARTICLES

Information on both the quantity and the chemical and physical characteristics of the fine particles emitted from various sources is needed to gauge accurately the importance of individual sources. During the current program, we attempted to compile information on chemical composition versus particle size. Unfortunately, our efforts were not very fruitful because data are almost nonexistent for most sources. Qualitative information on the types of potentially hazardous particulate pollutants that might be emitted from various industrial sources was obtained and is summarized in Table 26, pages 60 to 63.

METHODOLOGY FOR DETAILED EMISSION INVENTORIES USING NATIONAL EMISSION DATA SYSTEM

With the advent of EPA's National Emission Data System (NEDS), it is possible to consider conducting a detailed inventory of fine particle emissions on a variety of geographical bases. The NEDS data bank includes a

Table 4. ESTIMATED FINE PARTICLE EMISSIONS FROM MOBILE SOURCES, 1971

Source	Fine Particle Emissions (10^3 tons/year)
Motor vehicles	760
Aricraft	47
Railroads	46
Vessels	51
Nonhighway use of motor fuels	108
Total	1,012

Table 5. COMPARISON OF ESTIMATED FINE PARTICLE EMISSIONS FROM STATIONARY POINT, STATIONARY AREA, AND MOBILE SOURCES (0.01-7 microns)

Source Category	Fine Particle Emissions (10^6 tons/year)
Stationary point	5.8
Stationary area	2.8
Mobile	1.01
Total	9.61

vast source of information on various pollution sources, source operating conditions, control equipment usage and efficiency, and emission rates.

A review of the input-output format for the NEDS data bank disclosed that with minor modifications the NEDS program could be upgraded to include the capability to perform a detailed emission inventory of fine particulates for the entire U.S. and for selected geographical areas such as states or cities. The main modifications required to NEDS are: (1) addition of an equation to calculate fine particulate emissions from individual sources; (2) addition of fractional efficiency data for each control device; (3) addition of particle size distribution data for emissions from each operation; and (4) change in output format to include calculated fine particulate emissions. The methodology for detailed emission inventories using NEDS is presented on pages 64 to 80.

STATUS OF EMISSION INVENTORIES FOR FINE PARTICULATES

The development of an emission inventory for fine particulates requires a much broader and refined data base than that necessary for an inventory reported on a tonnage basis. Inadequacies in nearly all phases of the requisite data base severely restrict the accuracy as well as the comprehensiveness of any emission inventory of fine particulates. The most significant inadequacies are in the areas of particle size distributions of particles emitted from uncontrolled and controlled sources and fractional efficiency curves for various types of control devices. Major extrapolations have been necessitated by the lack of an adequate data base on particle size distributions and fractional efficiency of control equipment.

In summary, our current knowledge of the characteristics of emission sources and control equipment is such that only general indications of the levels of fine particulate emissions from various sources can be provided.

RECOMMENDATIONS FOR FUTURE WORK

In view of the increasing interest in the pollution problem from fine particulates, program(s) to upgrade the data base needed to perform emission inventories for fine particulates should be initiated. In order to refine existing emission inventories for fine particles, it will be necessary to improve our knowledge of: (1) production rates; (2) mass emission factors; (3) particle size distributions of emitted particulates; (4) types and extent of control equipment usage on various sources; and (5) fractional efficiency of control equipment.

Available information on production or consumption rates and emission factors is more reliable than is that on the other three factors. Priority in future programs should be given to refining the data base for Items 3, 4 and 5. In addition, because it is currently necessary to make major extrapolations of available data on particle size distributions and fractional efficiency, special emphasis should be placed on acquiring new and more reliable data for these two key factors. Field testing on selected control equipment-source combinations should be used to obtain the data on particle size distributions and fractional efficiency.

INTRODUCTION

Particulates emitted from industrial processes and various other sources of air pollution are distributed over a wide range of sizes from a few angstroms to several microns in diameter. While we have generally succeeded in controlling the large particulates and with them the major fraction of the mass emitted, we have not been nearly as successful in eliminating the particulates below about 2-5 µm in size (i.e., fine particulates). Control of fine particulates has received increasing attention in the last few years, because fine particles have a greater impact on human health, visibility, and atmospheric properties than do larger particles.

Increased awareness of the importance of fine particulate pollution has fostered discussion regarding programs and alternatives for controlling fine particle emissions. Formulation of control strategies, as well as the development of requisite control technology, for fine particulate pollutants requires input regarding the sources of fine particulate emissions and the quantities of fine particulates emitted from specific sources--i.e., an emission inventory of fine particulate pollutants.

The work presented in this report was designed to update and expand a previous emission inventory of fine particulates.[1] The program was conducted by MRI for the National Air Data Branch, Office of Air Quality Planning and Standards as Task Order No. 1, on Contract No. 68-02-1324. As in the original emission inventory, attention was focused on estimates of primary particulates, and not on secondary particulates formed by subsequent reaction of source emissions in the atmosphere. Both stationary point and area sources of fine particulates were included in the emission inventory for fine particles. The contribution of mobile sources to the primary fine particulate burden was also included in order to place the problem in prospective. The year of 1972 was selected as the base year for the emission inventory. In the previous emission inventory, the fine particle size range was defined to be 0.01-3 µ. The definition was revised in the current program to include particulates in the 0.01-7 µ size range.

The following sections of this report discuss data acquisition efforts, calculation of fine particle emissions from stationary point, stationary area and mobile sources, chemical and physical characteristics of fine particulates, methodology for detailed emission inventories using the National Emission Data System (NEDS), analysis of current state of the art of fine particle emission inventories, and recommendations for future work. Appendix A summarizes particle size distribution data used in the calculation of fine particle emissions from specific sources and Appendix B presents details of the calculations of emissions from specific sources.

INFORMATION ACQUISITION

Acquisition of data was an integral part of the program. To perform the emission calculations, data for the production or consumption rate, emission factors, fractional efficiency of control equipment, extent of control, and particle size distributions of emitted particulates must be known for each emission source.

Information on emissions from particulate pollution sources or control equipment applied to these emission sources was obtained from the MRI data bank[1/] and data acquisition activities conducted during the study. The data bank includes over 4,000 technical articles and reports; 500 stack sampling tests from air pollution control agencies; telephone and personal interview reports from 350 to 400 industrial, testing laboratory, and control device manufacturer contacts; and communiques from consultants and academic people. This data bank was searched for all pertinent data.

Contacts were made with various EPA personnel to obtain recent information on (1) particle size of emitted particulates, and (2) fractional efficiency characteristics of control equipment. The more aggressive control equipment manufacturers and several of the more active companies involved in source testing programs were also contacted. Data acquisition activities in specific information categories are discussed in more detail in the next sections.

PRODUCTION OR CONSUMPTION RATE DATA

The year of 1972 was selected as the base year for the emission inventory. The information sources used to obtain 1972 production or consumption rate data included:

1. Survey of current business,

2. Statistical abstracts,

3. U.S. industrial outlook,

4. Predicasts,

5. Miscellaneous trade publications,

6. Minerals yearbook, and

7. Telephone contacts.

Whenever 1972 data could not be obtained or were not available, the production or consumption rates for 1972 were estimated based on the most recent data available and the general trends indicated by comparison with previous years. Several of the information sources consulted also made predictions of 1972 production or consumption rates.

EMISSION FACTOR DATA

The information sources used for mass emission factors were:

1. "Compilation of Air Pollutant Emission Factors," AP-42 2nd Edition, April 1973,

2. Technical reports, and

3. MRI data bank.

The values in AP-42 were used in general, but in a few cases the values differed significantly from those in the MRI data bank. Closer examination revealed that the difference was due to the method of calculating average emission factors. The AP-42 emission factors are apparently based on the arithmetic average of the emission factors reported for individual sources. The MRI data bank emission factors are usually based on the geometric average of individual source emission factors whenever possible. The largest difference found was for cement kilns where AP-42 gives emission factors of 245 lb/ton and 228 lb/ton for dry process and wet process cement production, respectively. The geometric average of the MRI data bank is 167 lb/ton for both wet and dry process cement kilns. The 167 lb/ton emission factor was used in the emission calculations because it is believed that the geometric average is more representative of the emission source on a national scale.

FRACTIONAL EFFICIENCY CHARACTERISTICS OF CONTROL EQUIPMENT

Information sources used to obtain data on the fractional efficiency characteristics of control equipment included:

1. MRI data bank,

2. Recent industry studies by EPA, and

3. Telephone contacts.

The available fractional efficiency data apply to specific industry sources in only a few cases. Therefore, as in our previous study,[1/] the data were separated on the basis of control devices (i.e., cyclones, electrostatic precipitators, wet scrubbers and fabric filters). The fractional-efficiency data for each control device category were plotted on log-probability paper to magnify the efficiency relationship for the smaller particles.

The data spread for each type of device varied over a wide range, but this variation is not surprising when one considers the wide variation in types and design of devices (such as pilot unit vs. full-scale unit), testing procedures, operating conditions and analysis techniques. However, the data did, in most cases, reflect the expected efficiency characteristics of specific types of devices. That is, multiclones showed a higher efficiency curve than cyclones, and Venturi scrubbers showed a higher efficiency than low pressure drop scrubbers.

Since the data for each type of device did vary over a wide range, the curves were examined with the objective of drawing general curves that would represent low, medium, and high overall efficiencies for each type of control device. The data for each type of control device and the information regarding specific types of devices, operating conditions, and testing procedures were carefully assessed to determine the general fractional efficiency curves for each type of control device which best represents low, medium, and high overall efficiencies. The resulting general fractional efficiency curves were then extrapolated when necessary to the size range of interest to this program, i.e., 0.01-7 μ. Figure 1 presents the extrapolated fractional efficiency curves. Only one curve has been drawn for fabric filters due to limited data, and it was extrapolated as a straight line from below about 0.5 μ. These general fractional efficiency curves for each type of device represent the results of the evaluation of available fractional efficiency data, and they were used in calculating the quantity of fine particulates emitted from controlled industrial sources.

EXTENT OF CONTROL DATA

To determine the quantity of particulate emitted from a source to the atmosphere it is necessary to know if the source is controlled and the type of control device(s) used. This information (extent of control) was obtained from the following sources:

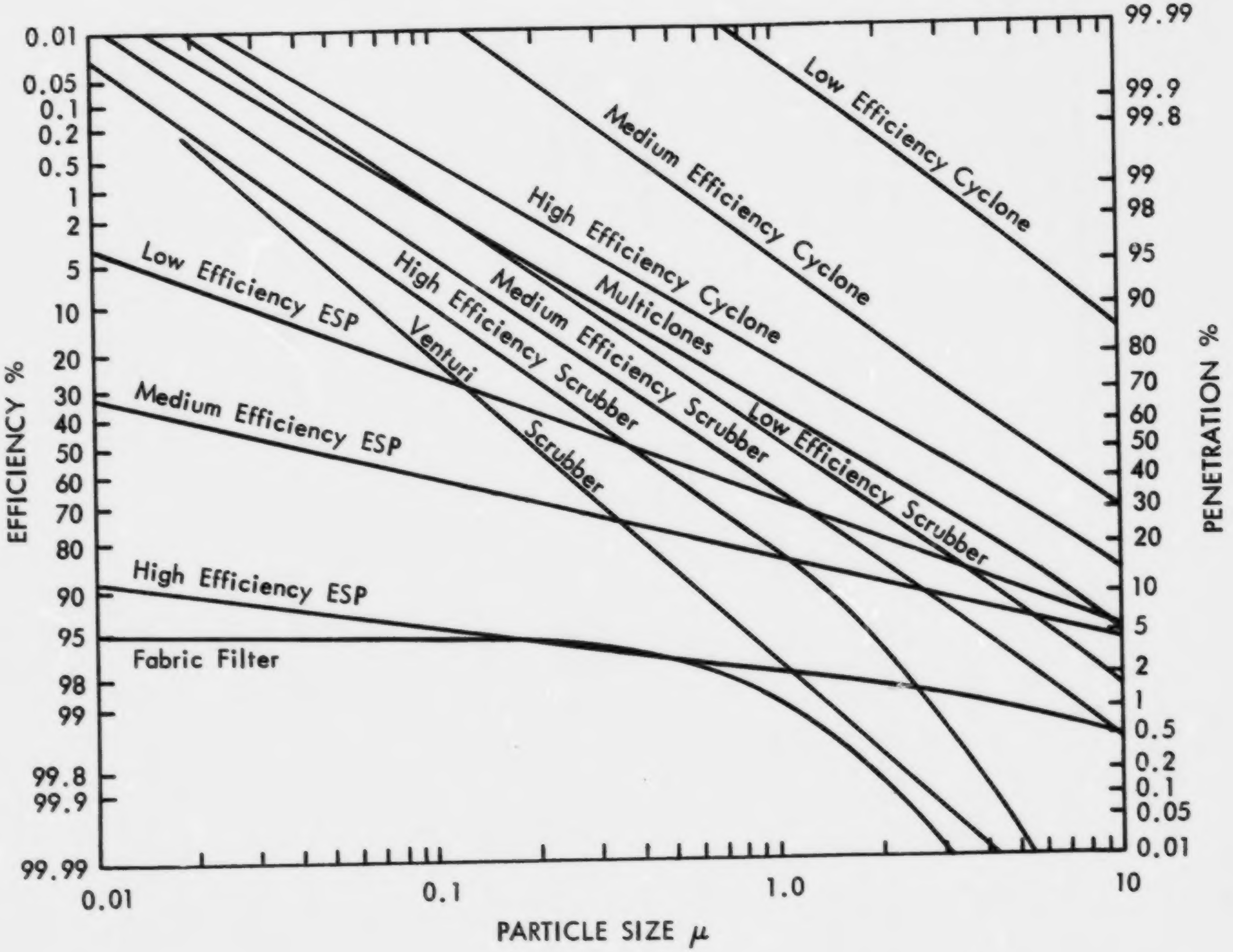

Figure 1. Comparison of control device fractional efficiency

1. MRI data bank,
2. EPA data bank (NEDS system),
3. Recent industry studies by EPA, and
4. Telephone contacts.

The MRI data bank contains the results of thorough extent of control surveys and these results were published as a part of our previous work.[2] Our efforts for this study were directed at updating the extent of control data to 1972 figures wherever significant changes in control device applications have occurred.

An attempt was made to compare the MRI extent of control data with data in the National Emission Data System (NEDS). For this comparison a condensed point source listing was supplied by the EPA project officer. Examination of the listing disclosed that insufficient information on source characteristics and control devices was provided, and a meaningful comparison with MRI's data could not be made in most cases.

The complete printout of each point source report would be required to permit a detailed comparison of extent of control data. However, because of the extensive time that would be required to acquire and analyze the complete printout of each source report, the existing MRI data on extent of control was used to make estimates of fine particulate emissions.

PARTICLE SIZE DISTRIBUTION DATA

The information sources for particle size distributions were:

1. MRI data bank,
2. Recent source testing by EPA and EPA contractors, and
3. Recent technical literature.

Available new particle size data were incorporated into the MRI data bank and the revised particle size distributions were used in the calculations for this study. In general, the particle size distribution data used in the calculations for stationary point sources are almost identical to that used in our previous work.[1] The only significant change was for ferroalloy plants which were divided into four groups--ferrosilicon alloys, ferromanganese alloys, ferrochromium alloys and miscellaneous ferroalloys. The division was made possible by the acquisition of new and more extensive particle size data and emission factors.

A major portion (over 95%) of the data currently available on the size of particulates emitted from industrial sources has been obtained by using standard source sampling procedures and the Bahco Micro-Particle Classifier. The Coulter Counter, Whitby centrifuge/MSA Sedimentation, and microscopic techniques have also been used for particle sizing. Cascade impactors, electrostatic precipitators, and thermal precipitators have been used to a limited extent in source sampling, and a small quantity of particle size data were obtained from investigators using this equipment. Since, in general, particle size distributions from uncontrolled sources and fractional efficiency curves are not available over the 0.01-7 μ range, it was necessary to extrapolate available data to this size range (see Figure 1).

FINE PARTICLE EMISSIONS

Estimates of fine particle emissions were made for three categories of sources: stationary point, stationary area, and mobile. The primary emphasis was placed on stationary point and area sources and the mobile sources were included to provide prospective to the problem of fine particle emissions. The procedures used to calculate fine particle emissions in each source category and the results of the calculations are discussed in the following sections.

PROCEDURES FOR CALCULATING FINE PARTICLE EMISSIONS

The procedures for calculating fine particle emissions for each source category are similar with the major difference resulting from the fact that stationary area and mobile sources are essentially uncontrolled sources of particulate pollutants. Calculation procedures for each source category are briefly reviewed in the following paragraphs.

Calculation Procedures for Stationary Point Sources

The procedure that was used to develop the inventory of fine particulate emissions for stationary point sources is identical to that used in our previous work.[1] The basic equation used to determine the quantity of fine particles emitted from a specific source is:

$$E_{d_1-d_2} = \frac{P\ e_f\ (C_t)}{2{,}000} \cdot f_1(d) \cdot f_2(d) \qquad (1)$$

where

d = Particle size in microns.

$E_{d_1-d_2}$ = Emission rate of particles between d_1 and d_2, tons/year.

e_f = Emission factor (uncontrolled), pound/ton.

P = Production rate, tons/year.

C_t = Percentage of production capacity on which control equipment is installed (for each specific type of control device).

$f_1(d)$ = Particle size distribution of emitted particulates.

$f_2(d)$ = 1 - fractional efficiency of control system (i.e., penetration).

The specific particle size ranges (d_1-d_2) included in the inventory are:

3-7 μ, 1-3 μ, 0.5-1.0 μ, 0.1-0.5 μ, 0.05-0.1 μ, 0.01-0.05 μ.

Because of inadequacies in the data base, it was not possible to estimate fine particle emissions from all industrial sources. The major source categories that were included are shown in Table 6.

Calculation Procedures for Stationary Area Sources

The calculation method for stationary area sources is essentially the same as for point sources except that neither the control device application nor control device penetration terms are needed. Equation (2) presents the equation used to determine the quantity of fine particles emitted from a specific source:

$$E_{d_1-d_2} = \frac{G\ e_f}{2,000} \cdot f_1(d) \qquad (2)$$

where

d = Particle size in microns.

$E_{d_1-d_2}$ = Emission rate of particles between d_1 and d_2, tons/year.

e_f = Emission factor (uncontrolled).

G = Source strength.

$f_1(d)$ = Particle size distribution of generated particulates.

Table 6. MAJOR STATIONARY POINT SOURCE CATEGORIES FOR FINE PARTICLE EMISSION INVENTORY

A. Asphalt--hot mix batch plants, dryer.

B. Cement plants--kiln.

C. Ferroalloy plants--electric arc furnace.

D. Fertilizer plants--granulators and dryers.

E. Iron foundries--cupola.

F. Kraft pulp mills--bark-fired boilers, recovery furnaces, and lime kilns.

G. Lime plants--rotary kilns.

H. Municipal incinerators.

I. Stationary combustion sources, electric utility and industrial boilers--coal-fired, oil-fired, and gas-fired.

J. Iron and steel plants--sinter machines, basic oxygen furnaces, open hearth furnace, and electric arc furnace.

The term G (source strength) is analogous to the production or consumption rate term in Eq. (1), but it is expressed in terms such as acres burned/year, number of buildings burned/year, or acres cultivated/year, rather than tons of material processed per year. Table 7 indicates the major stationary area sources that were considered in the emission inventory.

Calculation Procedures for Mobile Sources

Mobile sources were assumed to be uncontrolled sources of particulate pollutants, and Eq. (2), with the factors expressed in appropriate units, was used to calculate fine particle emissions from mobile sources. The major mobile sources included in the inventory are presented in Table 8.

CURRENT LEVEL OF FINE PARTICULATE EMISSIONS (1972)

The procedures outlined in the preceding sections were used to calculate fine particle emissions from each source category. The results of the calculations are highlighted in the next sections.

Stationary Point Sources

Equation (1) with the appropriate data for each individual source was used to calculate the mass of fine particles emitted from various stationary point sources. It was assumed that control equipment is in operation 100% of the time that a source is operating. That is, of course, not the case, but data are not available on control equipment operational efficiency. The details of the emission calculations for each point source are given in Appendix B. The results are summarized in the following sections.

Hot-Mix Asphalt Paving Plants - Asphalt is a raw material for several industries. Two of the more important with regard to air pollution are hot-mix asphalt paving plants and asphalt roofing manufacturing facilities. Particle size distribution and degree of application of control information were not available for the asphalt roofing manufacturing operations. As a result, fine particle emissions were determined only for the hot-mix asphalt paving plants.

The major source of dust in hot-mix asphalt paving plants is the rotary dryer. However, while dust from the rotary dryer is the greatest source, dust emitted from the vibrating screens, bucket elevator, storage bins, and weigh hopper is also significant. In some plants, the dryer dust problem is handled separately from the other sources. However, the trend is to combine both dryer and vent line sources (fugitive sources) together with a single collector fan system.

Table 7. MAJOR STATIONARY AREA SOURCES CONSIDERED IN FINE PARTICLE EMISSION INVENTORY

- A. Wildfires and prescribed burning
- B. Agricultural burning
- C. Structural fires
- D. Coal refuse banks (burning)
- E. Fugitive sources
  - a. Agricultural tillage
  - b. Construction sites
  - c. Aggregate storage piles
  - d. Vehicle traffic on unpaved roads

Table 8. MAJOR MOBILE SOURCES INCLUDED IN FINE PARTICLE EMISSION INVENTORY

- A. Motor vehicles
- B. Aircraft
- C. Railroads
- D. Vessels
- E. Nonhighway use of motor fuels

Fine particle emissions were estimated for both the rotary dryer and the vent line sources as shown in Table 9. Calculations are summarized in Tables B-1 to B-12 of Appendix B. Emissions are estimated at 287,689 tons/year smaller than 7 μ diameter from the dryer and vent sources. Particle size distributions for uncontrolled rotary dryers and vent lines are presented in Figures A-1 and A-2 of Appendix A. The particle size data in Figure A-1 were obtained from 20 individual dryers, while those in Figure A-2 were obtained from only two different vent lines.

Also shown in Table 9 is an estimate of the reliability of the individual terms used to calculate the fine particle emissions and the overall reliability. A ranking scale of 1 to 5 with 1 being the highest and 5 the lowest was used to indicate the reliability.

Cement Plants - In the source category of cement plant, calculations of fine particle emissions could be performed only for the rotary kilns. Calculations of emissions from dryers, grinders, and other miscellaneous sources could not be done with any reliability because of lack of information on emission factors, particle size distributions, and application of control.

Table 10 summarizes fine particle emissions for rotary cement kilns and gives the reliability of the emission calculation parameters and results. The emissions from cement kilns that are less than 7 μ in diameter are estimated to be 240,601 tons/year. Details of the emission calculations are given in Tables B-13 and B-19 of Appendix B.

The emission factor of 167 lb/ton used in the emission calculations is the geometric average of the data available in MRI's data bank. This emission factor differs significantly from the values of 245 lb/ton for dry process and 228 lb/ton for wet process kilns which are given in the Compilation of Air Pollutant Emission Factors, AP-42, 2nd Edition, April 1973. Apparently the AP-42 published values are based on an arithmetic mean rather than a geometric mean which we believe to be the better representation of the industry as a whole.

The extent of control data are based on a telephone survey which was conducted as a part of our previous study.[2] These survey values were updated from 1970 to 1972 by estimating the changes in control application, and by comparison with information obtained from EPA's National Emission Data System.

The particle size distribution data used in the calculations are shown in Figure A-3 of Appendix A. Figure A-3 is based on the composite of size distribution from 42 individual cement kilns.

Table 9. FINE PARTICLE EMISSIONS FROM HOT-MIX ASPHALT PLANTS

A. Summary of Fine-Particle Mass Emissions from Hot Mix Asphalt Plants

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Dryers	36,086	139,032	51,361	27,365	508	0	254,352
Vent lines	11,031	19,516	2,394	396	0	0	33,337
Total	47,117	158,548	53,755	27,761	508	0	287,689

B. Reliability Ratings for Fine Particle Emissions from Hot Mix Asphalt Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Dryers	2	2	2	2	3	2
Vent lines	2	2	2	3	3	3

Table 10. FINE PARTICLE EMISSIONS FROM CEMENT PLANTS

A. Summary of Fine-Particle Mass Emissions from Cement Plants

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Rotary kiln	102,544	101,650	24,421	11,703	283	0	240,601

B. Reliability Ratings for Fine Particle Mass Emissions from Cement Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Rotary kiln	1	3	2	3	3	3

Ferroalloy Plants - The production of ferroalloys has many dust or fume producing steps. Materials handling, crushing and grinding operations generate coarse dust, while the pyrometallurgical steps release metallic fumes. Particle size data were available only for the pyrometallurgical operations, and as a consequence, fine particle emissions were estimated only for these operations.

Because new and more extensive data for particle size distribution and emission factors for ferroalloys were acquired during this program, it was possible to divide the ferroalloy calculations into four production groups--ferrosilicon alloys, ferromanganese alloys, ferrochromium alloys and miscellaneous ferroalloys. The estimated fine particle emissions from each of the ferroalloy groups are summarized in Table 11. The total ferroalloy emissions less than 7 μ in diameter are estimated to be 302,143 tons/year. Also shown in Table 11 are the reliability ratings for the calculation parameters.

The calculations for the ferrosilicon alloys are shown in Tables B-20 to B-24 of Appendix B. The particle size distribution used in the calculations is for furnaces producing 50% FeSi and is shown in Figure A-4 of Appendix A. The production rate used in the calculations includes alloys of varying silicon content from silvery pig iron (< 25% Si) to silicon metal (> 95% Si). The emission factor used is the geometric average of the emission factors for alloys with varying silicon percentages weighted in terms of the appropriate production rate of each alloy. The application of control is based on a 1970 EPA study which included 40 furnaces producing ferrosilicon alloys. The result of the calculations is an estimate of 159,241 tons/year of particulate less than 7 μ in diameter from ferrosilicon alloy production.

The calculations for the ferromanganese alloys are shown in Tables B-25 to B-29 of Appendix B. The particle size distribution used in the calculations is for furnaces producing ferromanganese alloys and is shown in Figure A-5 of Appendix A. The production rate used in the calculations includes ferromanganese, silicomanganese, and ferrosilicomanganese alloys. The emission factor used is the geometric average of the emission factors weighted in terms of the production rates of the different ferromanganese alloys. The application of control is based on a 1970 EPA study which included 33 furnaces producing ferromanganese alloys. The result of the calculations is an estimate of 33,182 tons/year of particulate less than 7 μ in diameter from ferromanganese alloy production.

The calculations for the ferrochromium alloys are shown in Tables B-30 to B-33 of Appendix B. The particle size distribution, shown in Figure A-6 of Appendix A, used in the calculations is a composite based on furnaces producing high carbon ferrochrome and ferrochromium silicon. The production rate used in the calculations includes both ferrochrome and ferrochromium silicon and the emission factor used is based on the geometric

Table 11. FINE PARTICLE EMISSIONS FROM FERROALLOY PLANTS

A. Summary of Fine-Particle Mass Emissions from Ferroalloy Plants

	Particle Size Ranges (μ) Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Electric Arc Furnaces							
1. Ferrosilicon alloys	1,892	18,995	28,666	83,630	17,852	8,206	159,241
2. Ferromanganese alloys	3,158	15,784	9,593	4,623	24	0	33,182
3. Ferrochromium alloys	10,975	22,767	14,545	18,926	1,978	796	69,987
4. Miscellaneous alloys	3,848	12,000	9,409	13,012	1,084	380	39,733
Total	19,873	69,546	62,213	120,191	20,938	9,382	302,143

B. Reliability Ratings for Fine Particle Mass Emissions from Ferroalloy Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Electric Arc Furnace						
1. Ferrosilicon alloys	2	2	2	3	2	2
2. Ferromanganese alloys	2	2	2	3	2	2
3. Ferrochromium alloys	2	2	2	3	2	2
4. Miscellaneous alloys	3	3	2	4	3	3

average of the emission factors for the same alloys. The application of control is based on a 1970 EPA study which included 30 furnaces producing ferrochromium alloys. The result of the calculations is an estimate of 69,987 tons/year of particulate less than 7 μ in diameter emitted from ferrochromium alloy production.

Approximately 14% of all ferroalloy production is not covered by the ferrosilicon, ferromanganese, and ferrochromium alloy calculations. This production was designated miscellaneous ferroalloys and the calculations of emissions from the production of these alloys are given in Tables B-34 to B-38 of Appendix B. The emission factor used is the average of all the known emission factors for other ferroalloys. The particle size data used is a composite of the ferrosilicon, ferromanganese and ferrochromium particle size data used in the previous calculations. The application of control data is based on 112 furnaces producing all ferroalloys which were surveyed in a 1970 EPA study. The result of these calculations is an estimate of 39,733 tons/year of particulates emitted from miscellaneous ferroalloy production.

Fertilizer and Phosphate Rock - Particulate emissions from the processing of phosphate rock and from fertilizer manufacturing originate from dryers, roasters, digesters, granulators, and coolers. Particle size distributions were obtained only for granulators and dryers used in the manufacture of phosphate fertilizers. Figure A-7 of Appendix A presents the available particle size data for these sources. The data in Figure A-7 were obtained from eight individual fertilizer plants.

Because of the lack of adequate particle size distribution data for the other sources, estimates of fine particle emissions were made only for the granulators and dryers. Fine particle emissions from the granulation and drying processes are estimated to be 21,394 tons/year as shown in Table 12. Details of the calculations are given in Tables B-39 to B-42 of Appendix B.

The total production of granulated fertilizer was estimated as follows:

Ammonium phosphate - 2,080,000 tons as P_2O_5 at 40% =	5,200,000 tons
Salt grades - 126,000 tons as P_2O_5 at 21% =	600,000
Solid fertilizer (SIC No. 2872, plants which do not manufacture any of their raw materials) =	8,100,000
Total	13,900,000
Normal superphosphate - 798,000 tons as P_2O_5 at 19% =	4,200,000
Triple superphosphate - 1,530,000 tons as P_2O_5 at 45% =	3,400,000
Total	7,600,000
Assume 75% of superphosphates are granulated =	5,700,000
Total tonnage of granulated fertilizer =	19,600,000 tons

Table 12. FINE PARTICLE EMISSIONS FROM PHOSPHATE FERTILIZER PRODUCTION
(Granulation and Drying Only)

A. Summary of Fine-Particle Mass Emissions from Phosphate Fertilizer Plants

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Granulation and drying	5,274	8,678	3,768	3,310	364	0	21,394

B. Reliability Ratings for Fine Particle Mass Emissions from Phosphate Fertilizer Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Granulation and drying	3	4	2	3	4	4

Published data on emissions from granulation processes are meager and not indicative in every instance of what process equipment is being vented. An emission factor of 195 lb/ton for granulation dryers and coolers, which was obtained from data averaged for 15 plants over the country, was used in the calculations. This emission factor is the same value as was used in our previous emission inventory.[1,2] The extent of control application was taken from our previous study.[1,2]

Iron and Steel Plants - The major sources of particulate air pollution in iron and steel plants are: sintering machines, coke oven plants, blast furnace operations, steel-making furnaces, and materials handling operations. Fine particle emissions were estimated only for sintering machines and steel-making furnaces because of lack of particle size distribution data for the other sources. Table 13 summarizes the estimates that were made for this industry. The emission calculations for sinter machines and steel-making furnaces are reviewed in the following sections. The total estimated emission of particulates from these sources less than 7 μ in diameter is 492,210 tons/year.

Basic oxygen furnaces - Calculations of fine particle emissions from basic oxygen furnaces were hampered by a discrepancy in the reported particle size distributions for basic oxygen furnace dust. Reports have been made of 95% < 1 μ as well as 95% < 0.2 μ. Available particle size data are presented in Figure A-8, Appendix A. The curve with the triangle symbols was used for the emission calculations.

Tables B-43 to B-46 in Appendix B summarize the calculation of emissions. Emissions are estimated to be 361,563 tons/year for particulates less than 7 μ in diameter. This quantity is much greater than that reported for total mass emissions from basic oxygen furnaces.[2] This discrepancy results primarily from the calculation of fine particle emissions from BOF units controlled with Venturi scrubbers (Table B-46).

The emissions from BOF units that are controlled with Venturi scrubbers were computed using the particle size distribution for uncontrolled furnaces (Figure A-8), and the fractional efficiency curve for a Venturi scrubber (Figure 1). Since all available information indicates that the particulate emitted from these furnaces is nearly all micron or submicron in size, the large difference in the computed emissions appears to result from the fractional efficiency values for the Venturi scrubber given in Figure 1. The fractional efficiency curve for a Venturi scrubber indicates a collection efficiency of 92% for 1-μ particles, 88% for 0.5-μ particles, and 22% for 0.1-μ particles. The particle size distribution for basic

Table 13. FINE PARTICLE EMISSIONS FROM IRON AND STEEL PLANTS

A. Summary of Fine-Particle Mass Emissions from Iron and Steel Plants

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Basic oxygen furnaces	0	1,771	39,311	318,405	2,076	0	361,563
Electric arc furnaces	3,148	5,104	3,389	6,940	2,210	2,649	23,440
Open hearth furnaces	740	6,756	18,424	63,630	7,051	1,343	97,944
Sintering machine wind boxes	3,699	3,705	1,172	637	0	0	9,213
Total	7,587	17,336	62,296	489,612	11,337	3,992	492,160

B. Reliability Ratings for Fine Particle Emissions from Iron and Steel Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Basic oxygen furnaces	2	2	3	2	3	3
Electric arc furnaces	2	2	2	3	2	2
Open hearth furnaces	2	3	2	4	3	3
Sintering machine wind boxes	3	2	2	2	2	2

oxygen furnace dust (Figure A-8) shows 99% < 1 μ and 58% < 0.5 μ. Comparing this particle size distribution with the respective Venturi scrubber efficiencies indicates that the overall efficiency for a Venturi scrubber would be less than 88% on a typical basic oxygen furnace. This value of overall efficiency for a Venturi scrubber on BOF emissions seems quite low, particularly in view of field tests on Venturi scrubbers operating on BOF units that indicate 96-99% overall efficiency.[3,4]

Difficulties in sampling the outlet of Venturi scrubbers on basic oxygen furnaces may have led to erroneous conclusions regarding the overall efficiency. The exact sampling procedures used in the field tests were not defined. Standard sampling techniques are not adequate for sampling submicron particulates. If standard sampling trains were employed, it is possible that a significant portion of the particulate leaving the scrubber would not be collected. Failure to collect part of the material leaving the scrubber would result in the calculation of a higher than actual efficiency for the control device.

Comparison of the fraction efficiency curve in Figure 1 with the theoretical and measured overall efficiencies does not resolve the large difference in the calculated emissions. This raises the possibility that the particle size distributions for basic oxygen furnace dust are not correct. Meager data are available on the particle size of BOF dust. Only two particle size distributions were found, therefore, it is possible that the data shown in Figure A-8 are not representative of BOF dust. However, previous telephone contacts with knowledgeable people in the iron and steel industry, indicated that primary BOF dust (i.e., unagglomerated) is predominantly submicron in size.[5,6]

It is also possible that the particle size which a control device "sees" is not the same as that reported in Figure A-8. As noted in the preceding paragraph, the data in Figure A-8 are assumed to represent primary particulates. BOF dust is mainly red iron oxide which has a high tendency to agglomerate. If the dust is transported through a hooding and ducting system before it enters a control device, considerable agglomeration may occur. In this event, the particles would be larger than shown in Figure A-8, and the efficiency of a control device would be correspondingly higher. Also the fractional efficiency curve for a Venturi scrubber shown in Figure 1 was not obtained for a scrubber collecting basic oxygen furnace dust, but rather for a dust that had low agglomeration tendencies. In passage through a scrubber BOF dust may agglomerate more than a dust that has a lower agglomeration tendency. Therefore, a Venturi scrubber might exhibit a high efficiency because of the agglomeration characteristics of BOF dust.

All of the above factors probably contribute to the differences between the calculated total and fine particle mass emissions. This case clearly indicates the many pitfalls involved in calculating fine particle emissions from generalized fractional efficiency curves, extrapolated particle size data, and inadequate information on particulate sampling procedures.

Electric arc furnaces - Limited particle size data are available for the electric arc furnace. As was the case with the other steelmaking furnaces, there is also considerable spread between individual particle size distributions. Figure A-9, Appendix A, presents the available particle size data. The arithmetic mean curve was used for the emission calculations summarized in Tables B-47 to B-52 in Appendix B. Particulate emissions less than 7 μ are estimated at 23,440 tons/year.

Open hearth furnaces - Estimates of the fine particle emissions from open hearth furnaces proved to be difficult because data on particle size distributions from uncontrolled or controlled furnaces are almost nonexistent. Furthermore, there are inconsistencies in the available information. Another complication is that the mass rate of emissions, and the particle size of the emitted material changes during the furnace cycle.

The particle size data shown in Figure A-10 of Appendix A were used in the fine particle emission calculations which are summarized in Tables B-53 to B-56 in Appendix B. The particle size data reported in Figure A-10 are a composite of data obtained by using two sampling trains:

1. Glass cloth thimble ahead of a Whatman paper thimble, and

2. A thermal precipitator.

Particle sizing was accomplished by optical techniques. The samples were collected between charging periods and early in the melting period. Although other data which differ greatly are available it is believed that the data shown in Figure A-10 are the best for use in the fine particle calculations.

Accurate application of control data for open hearth furnaces were difficult to obtain because of the rapid decline in steel production by use of open hearth furnaces. Production of steel by open hearth furnaces has dropped from approximately 66 million tons in 1968 to 32 million tons in 1972. In our previous study, a telephone survey indicated that 41% of open hearth production had emission controls in 1968.[2/] Assuming that the majority of the decline in steel production from open hearth furnaces has been due to the closing of uncontrolled furnaces, we estimated that the 1972 application of control would be 85% among the furnaces that remain in production. Particulate emissions which are less than 7 μ in diameter are estimated at 97,994 tons/year.

Sinter machines - Details of the calculation of fine particle emissions from sinter machines are presented in Tables B-57 to B-61 of Appendix B. Fine particle emissions from sinter machine windboxes are estimated to be 9,213 tons/year. Other emission sources from sintering machines were not estimated because of a lack of particle size data.

Particle size distributions for both uncontrolled and controlled sinter machine windboxes are illustrated in Figure A-11, Appendix A.

Iron foundries - The iron melting process in foundries is the principal source of particulate emissions. Cupola, electric arc, electric induction, and reverberatory air furnaces are used to obtain the molten metal. Secondary sources of particulates include materials handling, casting shakeout systems, buffing and grinding operations, and core ovens. Particle size distributions, emission factors, and degree of application of control information were available only for the cupola furnaces and estimates of fine particle emissions were confined to that source. Table 14 summarizes the fine particle emissions from cupolas and indicates the reliability of the calculations. The total particulate emissions less than 7 μ in diameter were estimated to be 19,375 tons/year. Details of the calculations are given in Appendix B, Tables B-62 to B-68.

The particle size data for uncontrolled cupolas are presented in Figure A-12 of Appendix A. The data in Figure A-12 were obtained from 25 individual cupolas. The emission factor used in the calculations is from Compilation of Air Pollutant Emission Factors, AP-42. The production rate used in the calculations in Table B-63 and the application of control data are based on Ref. 2 and recent trends indicated by the A. T. Kearny Company.[7]

Forest products industry - The forest products industry encompasses forestry, sawmill, plywood, particleboard, hardboard, and pulp mill operations. Only in the kraft pulp mill operations were sufficient particle size and application-of-control data available to permit an estimate of the fine particle emissions. Fine particle emissions from kraft pulp mills are given in Table 15. Individual sources in the kraft pulp mills are discussed in the following sections.

Bark-fired boilers - Many of the pulp mills utilized wood wastes as feed to the boiler plants. Reported particle size distributions for particulate effluents from five separate uncontrolled bark boilers are presented

Table 14. FINE PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS

A. Summary of Fine-Particle Mass Emissions from Iron Foundries

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Cupolas	6,074	6,466	2,458	3,275	544	544	19,375

B. Reliability Ratings for Fine Particle Emissions from Iron Foundries

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Cupolas	2	2	2	3	2	2

Table 15. FINE PARTICLE EMISSIONS FROM KRAFT PULP MILLS

A. Summary of Fine-Particle Mass Emissions from Kraft Pulp Mills

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Bark fired boilers	59,321	58,788	14,746	7,319	253	84	140,511
Recovery furnaces	28,019	123,236	100,800	96,579	1,862	130	350,626
Lime kilns	1,150	2,127	275	104	0	0	3,656
Total	88,490	184,151	115,821	104,002	2,115	214	494,793

B. Reliability Ratings for Fine Particle Emissions from Kraft Pulp Mills

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Bark fired boilers	3	3	2	3	3	3
Recovery furnaces	1	2	3	3	2	2
Lime kilns	3	3	2	3	4	4

in Figure A-13 of Appendix A. Tables B-69 to B-72 in Appendix B, summarize fine particle emission calculations for the bark boilers. Particulate emissions less than 7 µ are estimated at 132,724 tons/year. The procedure used to determine the uncontrolled emissions is given in Table B-70 since an exact production rate could not easily be determined. The method for calculating the application of control is also given in Table B-70. Both calculations depend greatly on the work previously reported in Ref. 2.

Recovery furnaces - The recovery furnace is the major source of particulate emissions in kraft pulp mills. Because of the extreme fineness, hygroscopic nature, and impaction characteristics of recovery furnace dust, it is difficult to collect a sample for size analysis. Available particle size distribution data are presented in Figure A-14, Appendix A. A small electrostatic precipitator and a Cascade impactor were used for sampling. Particle sizing was performed with an electron microscope. Tables B-73 to B-76 summarize the estimates of emissions from recovery furnaces. The total obtained for the particulate emission less than 7 µ in diameter was 350,626 tons/year. Since a variety of emission control devices with unknown fractional efficiencies are used on some recovery furnaces, the control devices were all assumed to be equal to medium efficiency electrostatic precipitators which are used on most installations. The application of control figures were taken from our previous study.2/

Pulp mill lime kilns - Data on particle size distributions from either uncontrolled or controlled pulp mill lime kilns are nearly nonexistent. Figure A-15 of Appendix A illustrates the only particle size distribution that was found during our previous study.1/ Additional data were not obtained in the current study. The sampling technique used to obtain the material for subsequent particle sizing was not given; however, microscopic techniques were used for the determination of the size distribution. Since an adequate number of particle size distributions were not available, only a gross estimate of fine particle emissions from lime kilns in pulp mills was made. It should be noted that the particle size data for pulp mill lime kilns presented in Figure A-15 shows only 7% less than 7 µ in diameter, while commercial lime industry kilns have 25% less than 7 µ in diameter as shown in Figure A-16.

Tables B-77 to B-80 of Appendix B summarize the calculation of fine particle emissions for the pulp mill lime kilns. Fine particle emissions total only 3,656 tons/year. However, if the particle size distribution for the commercial lime industry kilns had been used, the fine particle emissions would be approximately 43,400 tons/year.

Lime Plants - The major particulate emission source in lime plants is the rotary calcining kiln. Secondary sources include materials handling crushing, and screening operations. Table 16 summarizes fine particle emissions from lime plants. Individual sources are discussed in the following sections.

Rotary kilns - Calculations of the estimates of fine particle emissions from rotary kilns are presented in Tables B-81 to B-86 of Appendix B. Emissions of particulates less than 7 µ in diameter are estimated to be 116,502 tons/year.

The particle size distributions for uncontrolled kilns that were used in the emission calculations are shown in Figure A-16 of Appendix A, which is based on data that were obtained from 19 individual kilns. Information on application of control was obtained by using data from the telephone survey of lime plants reported for 1968 in Ref. 2 and estimating the changes in application between 1968 and 1972. The total 1972 lime production rate was obtained from the National Lime Association. Rotary lime kilns account for 80% of lime production so only 80% of the total production was used in the calculations. The other 20% of production is mainly from vertical kilns which have a much lower emission factor and were not included in the calculations.

Secondary sources - Calculations of the estimates of fine particle emissions from lime plant secondary sources are given in Tables B-87 to B-90. The emissions of particulates less than 7 µ in diameter are estimated to be 78,434 tons/year.

The particle size data used in the calculations for secondary sources are shown in Figure A-17 of Appendix A, which was based on two crushing and one screening operation. As a result of the telephone survey reported in Ref. 2, the application of control was estimated at 80%; however, there was not sufficient data to itemize the different control devices used. Therefore, for purposes of the emissions calculations it was assumed that all lime plant secondary sources were controlled by medium efficiency wet scrubbers.

Municipal Incineration - Estimates of fine particle emissions from municipal incineration and the reliability ratings for the calculations are given in Table 17. The particulate emissions less than 7 µ in diameter are estimated to be 33,106 tons/year. Details of the calculations used to make this estimate are given in Tables B-91 to B-97 in Appendix B. The individual parameters used in the calculations are discussed in the following paragraphs.

Table 16. FINE PARTICLE EMISSIONS FROM LIME PLANTS

A. Summary of Fine-Particle Mass Emissions from Lime Plants

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Rotary kiln	27,797	39,559	19,081	24,703	3,177	2,185	116,502
Secondary sources	23,950	44,629	8,483	1,372	0	0	78,434
Total	51,747	84,188	27,564	26,075	3,177	2,185	194,936

B. Reliability Ratings for Fine Particle Emissions from Lime Plants

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Rotary kiln	1	2	2	2	2	2
Secondary sources	2	3	4	4	3	4

Table 17. FINE PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS

A. Summary of Fine-Particle Mass Emissions from Municipal Incinerators

	Particle Size Ranges (μ)						
	Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
Incineration	4,551	9,058	5,564	8,642	2,100	3,191	33,106

B. Reliability Ratings for Fine Particle Emissions from Municipal Incinerators

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
Incineration	2	2	2	3	2	2

The 1972 incineration rate of 18 million tons/year was obtained from a telephone contact with a university researcher.[8] This value is the same as reported in the EPA data file of nationwide emissions, 1971.[9] The emission factor and application of control are largely based on a study by A. D. Little.[10] The application of control devices was updated by including a number of electrostatic precipitators which were scheduled to be installed between 1968 and 1972.

The particle size distribution used for the calculations is shown in Figure A-18 of Appendix A. This distribution is based on data from two sources--the MRI data bank and data published by Southern Research Institute. The MRI data includes that of the A. D. Little study.[10]

Stationary Combustion Sources - Stationary combustion sources presented in the inventory include electric utility and industrial boilers fired with coal, oil and gas. The estimates of fine particle emissions for each category are discussed in the following sections.

Electric utilities--coal-fired boilers - Fine particle emissions from electric utility coal-fired boilers are summarized in Table 18. Total emission of particulates less than 7 μ is estimated to be 1,858,241 tons/year. Fine particle emissions for pulverized coal-fired boilers are presented in more detail in Tables B-98 to B-103. Emissions for stoker coal-fired boilers are shown in Tables B-104 to B-108, while those for cyclone coal-fired boilers are summarized in Tables B-109 to B-113.

Particle size distributions for the various uncontrolled boilers are presented in Figures A-19, A-20, and A-21 of Appendix A. The data for pulverized coal-fired boilers in Figure A-19 represent size distributions from more than 300 individual boilers. Figure A-20 represents data from nine stoker coal-fired boilers, while Figure A-21 summarizes particle size distributions obtained from seven cyclone coal-fired boilers. Percent application of control and the percent controlled by different control devices was obtained from a phone survey reported in Ref. 2.

Industrial power plants--coal-fired boilers - Details of the calculations of fine particle emissions from pulverized coal-fired industrial power plants are summarized in Tables B-114 to B-118, for stoker coal-fired boilers in Tables B-119 to B-123, and for cyclone coal-fired boilers in Tables B-124 to B-128. Emissions of particulates less than 7 μ in diameter are estimated to be 431,593 tons/year.

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Table 18. FINE PARTICLE EMISSIONS FROM STATIONARY COMBUSTION SOURCES

A. Summary of Fine-Particle Mass Emissions from Stationary Fuel Combustion

	Particle Size Ranges (μ) Tons/Year						
Source	3-7	1-3	0.5-1.0	0.1-0.5	0.05-0.1	0.01-0.05	Total
A. Coal							
1. Electric utility							
a. Pulverized	665,771	659,398	199,449	110,988	3,128	0	1,638,734
b. Stoker	57,308	23,295	5,878	2,138	0	0	88,619
c. Cyclone	53,088	53,792	15,706	8,097	205	0	130,888
2. Industrial							
a. Pulverized	68,980	22,072	795	0	0	0	91,847
b. Stoker	192,960	84,520	10,941	3,138	0	0	291,559
c. Cyclone	11,766	19,994	9,974	6,124	258	71	48,187
B. Fuel Oil							
1. Electric utility and industrial	190,665						190,665
C. Natural Gas and LPG							
1. Electric utility and industrial	—	104,895	—	—	—	—	104,895
Total	1,240,538	967,966	242,743	130,485	3,591	71	2,585,394

B. Reliability Ratings for Fine Particle Emissions from Stationary Fuel Combustion

	Parameters Used in Calculations					
Source	Production Rate	Emission Factor	Fractional Efficiency of Control Devices	Extent of Control Application	Particle Size Distribution	Overall Rating
A. Coal						
1. Electric utility	1	1	2	2	1	1
2. Industrial	2	2	2	3	2	2
B. Fuel Oil						
1. Electric utility and industrial	2	2	Unknown	Unknown	4	3
C. Natural Gas						
1. Electric utility and industrial	2	2	Unknown	Unknown	4	3

Available particle size distribution data are presented in Figure A-22 of Appendix A. The particle size measuring method used to obtain the size distributions is not known. The percent application of control and the percent controlled by different control devices was obtained from Ref. 2.

Electric utilities and industrial oil and gas-fired boilers - Accurate size data are not available for the particulates emitted from oil and gas-fired boilers, either for electric utility or industrial units. The meager data available indicated that emitted particulates were generally 90 wt % less than 7 μ for oil-fired boilers and 90 wt % less than 3 μ for gas-fired boilers.

Available information also indicates that these units are nearly all uncontrolled. The uncontrolled quantities of particulate emissions from the combustion of different types of fuel oil were estimated as follows:

A. Electric utilities

$$E = 14{,}200{,}000{,}000 \text{ gal. fuel oil} \times \frac{\text{8-lb particulate}}{\text{1,000 gal.}} \times \frac{\text{1 ton}}{\text{2,000 lb}}$$

$$= 56{,}800 \text{ tons.}$$

B. Industrial

1. Residual

$$E = 11{,}200{,}000{,}000 \text{ gal. fuel oil} \times \frac{\text{23-lb particulate}}{\text{1,000 gal.}} \times \frac{\text{1 ton}}{\text{2,000 lb}}$$

$$= 128{,}800 \text{ tons.}$$

2. Distillate

$$E = 3{,}500{,}000{,}000 \text{ gal. fuel oil} \times \frac{\text{15-lb particulate}}{\text{1,000 gal.}} \times \frac{\text{1 ton}}{\text{2,000 lb}}$$

$$= 26{,}250 \text{ tons.}$$

By combining the uncontrolled emissions and the available particle size data, particulate emissions less than 7 μ in diameter were estimated to be about 190,665 tons/year from oil-fired boilers.

The uncontrolled quantities of particulate emissions from the combustion of natural gas were calculated as follows:

A. Electric utilities

$$E = 4{,}320{,}000 \text{ million cubic feet gas} \times \frac{15\text{-lb particulate}}{\text{million cu ft}} \times \frac{1 \text{ ton}}{2{,}000 \text{ lb}}$$

$$= 32{,}400 \text{ tons.}$$

B. Industrial

$$E = 9{,}350{,}000 \text{ million cubic feet gas} \times \frac{18\text{-lb particulate}}{\text{million cu ft}} \times \frac{1 \text{ ton}}{2{,}000 \text{ lb}}$$

$$= 84{,}150 \text{ tons.}$$

The total of 116,550 tons/year of uncontrolled particulate from the combustion of natural gas in electric utility and industrial boilers and available particle size data were used to obtain the estimate of 104,895 tons/year less than 3 μ in diameter shown in Table 18. A recent publication by Battelle[11] states that an emission factor of 6 lb/ton would be a better value than the EPA emission factors reported in Ref. 12 which were used in the above calculations. If so, the total uncontrolled particulate would be reduced to 41,010 tons/year and the fine particle emission estimate would be reduced to 36,409 tons/year.

Miscellaneous Stationary Point Sources - Limited information is available for several additional industrial sources of fine particulates. Detailed estimates could not be made for these sources, but gross estimates of fine particulate emissions from these sources were made in our previous study. Since little additional information was obtained to improve the emission calculations for these sources, the previous calculations were updated by multiplying the previous emission estimates by the ratio of 1972 production to 1968 production. The updated emission estimates are presented in Table 19.

Stationary Area Sources

Fine particle emissions from area sources were calculated using Eq. (2), page 21, and the appropriate data for each individual source. Wildfires, prescribed burning, agricultural burning, structural fires, burning coal refuse banks and fugitive dust sources such as unpaved roads and airstrips, construction sites, agricultural tillage, and aggregate storage piles were included in the category of stationary area sources. However, it was not possible to make estimates of the fine particle emissions from the fugitive dust sources because of lack of data on source strengths (i.e., the term, G, in Eq. (2), page 21). Information on emission factors for the fugitive

Table 19. GROSS ESTIMATES OF FINE PARTICLE EMISSIONS FROM SELECTED INDUSTRIAL SOURCE CATEGORIES

Source	Estimated Fine Particle Emission[a/] (10^3 tons/year)
Crushed stone	868
Secondary nonferrous metallurgy	127
Petroleum FCC units	50
Coal preparation plants, thermal dryers	42
Carbon black	39
Acid plants	
A. Sulfuric	2.8
B. Phosphoric (thermal)	1.2
Total	1,130.0

---

a/ Estimated particulate emissions less than 7 μ in diameter.

sources is presented in later sections. Individual stationary area sources are discussed next.

Wildfires and Prescribed Burning - Wildfires (forest fires) and prescribed burning both generate significant quantities of particulate pollutants which are released into the atmosphere. Naturally, the contribution of forest fires may go up or down, depending upon the severity of a particular fire year. Prescribed burning has become an indispensable tool of forest management and it is designed to cure ailments of the forest--ailments that include undesirable fuel accumulations, the encroachment of unwanted species, unattractive wildfire habitats, and regeneration-inhibiting ground cover.

Currently, only limited data are available concerning the amounts of particulate matter released into the atmosphere by the combustion of forest fuels. Table 20 summarizes data reported by the Southeastern Forest Experiment Station, Southern Forest Laboratory, USDA.[13] In general, investigators at the Southern Forest Fire Laboratory have found that:

1. Dead forest fuels produce less particulates than live, green fuels.
2. Backfires* produce less particulates than head fires.**
3. There is a direct relationship between fuel moisture content and particulate production.
4. The heavier the fuel loading, the greater the particulate production.
5. Glowing combustion often produces more smoke than active combustion.

Reference 14 indicates that the average measured particulate produced from a wildfire is 58 lb/ton of fuel consumed while for a prescribed fire the particulate generation rate is 17 lb/ton. Darley, et al.,[15] reported that laboratory tests on Georgia pine needles showed that particulate yields from head fires varied from 53 to 69 lb/ton of fuel consumed, whereas backfires yielded 15 lb/ton of fuel consumed, confirming field observations that backfires are cleaner than head fires. Sandberg and Martin have conducted laboratory burning studies with fuel beds of about 13 lb and have reported the following emission factors based on the weight of fuel burned:[16]

Douglas-fir slash without needles--6.2 ± 3 lb/ton,

Douglas-fir slash with needles--24.2 ± 8 lb/ton,

Ponderosa pine slash--13.9 ± 2 lb/ton.

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* Backfire--a fire that moves in direction opposite to the wind.

** Head fire--a fire that moves in the same direction as the wind.

Table 20. PARTICULATE EMISSIONS FROM FOREST FIRES--INFLUENCE OF FUELS AND BURNING CONDITIONS

Burning Conditions	Particulate Emissions (per ton of fuel consumed)
Live, green vegetation burned with no wind	100 lb particulates
Live, dry vegetation (exposed to heat or open flames) burned with no wind	30 lb particulates
Dead, dry vegetation burned with a head fire	44 lb particulates
Dead, dry vegetation burned with a backfire	17 lb particulates

For the purposes of this inventory, wildfires were assumed to be similar to head fires and an emission factor of 60 lb/ton of fuel consumed was chosen for subsequent calculations. An emission factor of 17 lb/ton was selected for prescribed fires.

Data on the size distribution of particulates emitted from wildfires or prescribed fires are meager. Available data are shown in Figure A-23, Appendix A. The data for wood smoke particles indicate that nearly 99% of the particulates are less than 0.2 μ in size. Using the particle size data in Figure A-23, Appendix A, and the emission factors chosen in the preceeding paragraph, particulate emissions from wildfires and prescribed fires were calculated.

Total mass emissions and fine particulate emissions from forest fires are summarized in Table 21. Data on acreage consumed by wildfires and wildfire fuel consumption in 1971 were obtained from Yamate.17/ As shown in Table 21, total mass emissions from forest fires in 1971 are estimated at 2.16 x 10^6 tons, with all of the emitted particulates less than 0.5 μ in size.

Prescribed buring is the source of a much smaller amount of particulate emissions than are wildfires. Total mass emissions from prescribed burning are estimated at 178,330 tons in 1971 as shown in Table 22. Acreage consumed and fuel consumption were obtained from estimates by the U.S. Forest Service.18/ Reference 17 indicates that the particle size distribution for particulates emitted from prescribed fires is essentially the same as for wildfires, and, therefore, all the particulates emitted from prescribed fires are estimated to be less than 0.5 μ in size.

Agricultural Burning - Almost 32 million tons of agricultural waste are burned annually in the United States.19/ These wastes include crop residues, scrubbrush, weeds, grass and other vegetation. An emission factor of 17 lb/ton was applied to the total fuel consumption to obtain the emission estimate of 272,000 tons of particulate per year, as shown in Table 23. The average of the particle size distribution data for citrus prunings, rice straw, and sugar cane leaves shown in Figure A-24, Appendix A, was used to estimate the quantity of particulate in various size ranges.15/

Structural Fires - The National Fire Protection Association estimated that about 1 million buildings were attached by fire during 1971 with the average

Table 21. FINE PARTICULATE EMISSIONS FROM WILDFIRES (FOREST FIRES)

Geographic Area	Wildfire Fuel Consumption (ton/acre)[a]	Acreage Consumed (acres)[a]	Emission Factor (lb/ton of fuel)	Total Particulate Emissions (ton/year)	Fine Particle Emissions (ton/year)					
					3-7 μ	1-3 μ	0.5-1.0 μ	0.1-0.5 μ	0.05-0.1 μ	0.01-0.05 μ
1. Rocky Mountain group										
a) Northern Region 1	60	351,563	60	632,813	0	0	0	145,547	360,703	126,563
b) Rocky Mountain Region 2	30	162,795	60	146,516	0	0	0	33,699	83,514	29,303
c) Southwestern Region 3	10	206,983	60	62,095	0	0	0	14,282	35,394	12,419
d) Intermountain Region 4	8	53,064	60	12,735	0	0	0	2,929	7,259	2,547
2. Pacific group										
a) California Region 5	18	46,941	60	25,348	0	0	0	5,830	14,448	5,070
b) Alaska Region 10	16	1,046,542	60	502,340	0	0	0	115,538	286,334	100,468
c) Pacific N.W. Region 6	60	67,655	60	121,779	0	0	0	28,009	69,414	24,356
3. Southern group	9	1,992,339	60	537,932	0	0	0	123,724	306,621	107,586
4. North Central group	11	232,749	60	76,807	0	0	0	17,666	43,780	15,361
5. Eastern group	11	116,251	60	38,363	0	0	0	8,823	21,867	7,673
			Total	2,156,728	0	0	0	496,047	1,229,334	431,346

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[a] Based on 1971 U.S. Forest Service estimates.

Table 22. PARTICULATE EMISSIONS FROM PRESCRIBED BURNING IN 1971

Geographic Area	Consumption (ton/acre)	Acreage Burned (acres)	Emission Factor (lb/ton of fuel)	Total Particulate Emissions (ton/year)	Fine Particle Emissions (ton/year)					
					3-7 µ	1-3 µ	0.5-1.0 µ	0.1-0.5 µ	0.05-0.1 µ	0.01-0.05 µ
East	3	2,660,000	17	67,830	0	0	0	15,601	38,663	13,566
West	50	260,000	17	110,500	0	0	0	25,415	62,985	22,100
			Total	178,330	0	0	0	41,016	101,648	35,666

Table 23. PARTICULATE EMISSIONS FROM AGRICULTURAL BURNING IN 1971

Fuel Consumed (tons)	Emission Factor (lb/ton of fuel)	Total Particulate Emissions (ton/year)	Fine Particle Emissions (tons/year)					
			3-7 µ	1-3 µ	0.5-1.0 µ	0.1-0.5 µ	0.05-0.1 µ	0.01-0.05 µ
32 x 10^6	17	272,000	4,216	19,584	32,640	127,840	39,440	43,520

extent of damage being about 40%. Reference 20 indicates that the average house contains nearly 17 tons of wood and other combustible material.

By applying an average emission factor of 17 lb/ton wood combustion and assuming that the particle size of the emitted particulate is the same as that used for wildfires and prescribed fires, the estimated total mass emissions and fine particulate emissions shown in Table 24 were calculated.

Burning Coal Refuse Banks - Reference 21 states that 270 million tons of burning coal exist in refuse banks in the United States. It has also been estimated that the average life of a coal bank is 20 years.[21/] Using an emission factor for coal combustion of 17 lb of particulates per ton of coal burned, approximately 114,750 tons of particulates were emitted during 1971. Although particle size data are not available on the emissions from coal refuse banks, it is reasonable to assume that it is predominately less than 2 μ. Therefore, fine particulate emissions from burning coal refuse banks are estimated to be the same as total mass emissions: namely, 114,750 lb of less than 2 μ particles.

Fugitive Dust Sources - Fugitive dust sources* make significant contributions to background particulate levels in ambient air. Fugitive dust sources involve industrial operations (e.g., materials handling, storage piles, open mining or quarrying) as well as wide variety of categories such as unpaved roads, agricultural tilling and construction activity.

MRI recently completed a program for EPA (Contract No. 68-02-0619) to develop emission factors for estimating atmospheric emissions from certain common sources of fugitive dust.[26/] The source categories studied were:

- Unpaved roads and airstrips
- Agricultural tilling
- Construction sites
- Aggregate storage sites

Information is currently not available on the number, extent, or strength of the above sources and an inventory of fine particle emissions for

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* Fugitive dust emissions are defined as emissions which are not confined in process streams.

Table 24. PARTICULATE EMISSIONS FROM STRUCTURAL FIRES IN 1971

Buildings Attacked	Average Extent of Damage (%)	Average Fuel Content (ton/building)	Emission Factor (lb/ton of fuel)	Total Mass Emissions (ton/year)	Fine Particle Emissions (ton/year)					
					3-7μ	1-3μ	0.5-1.0μ	0.1-0.5μ	0.05-0.1μ	0.01-0.05μ
1×10^6	40	17	17	57,800	0	0	0	13,294	32,946	11,560

these sources could not be performed. A discussion of the emission factors for each of the above source categories is presented in the next sections.

Unpaved roads and airstrips - The emissions of dust from unpaved roads (per vehicle mile of travel) is directly proportional to the average traffic speed and to the silt content of the road surface. Emissions are reduced during periods of rainfall, but quickly return to normal levels. Of the total dust emissions, i.e., those particles which drift beyond about 20 ft from the edge of the road, about one-third have localized impact, one-third have medium range drift potential and about half are in the fine particle range.

The equation for estimating the total amount of road dust emissions with appreciable drift potential, i.e., particles smaller than 100 to 150 μ in diameter, is as follows:

$$e_{(roads)} = 0.81\ s\ (S/30) \qquad (3)$$

where e = emission factor (lb/vehicle mile),

s = silt content of road surface material (percent), and

S = average vehicle speed (mph).

The above equation applies to "dry" days; emissions are assumed to be negligible on days with rainfall exceeding 0.01 in. The silt content is the percent of dry surface material passing a 200-mesh screen. The accuracy of the above equation in predicting the results of field testing of emissions from unpaved roads is ± 10%.

On the average the dust emissions from unpaved roads can be separated into three size ranges, as follows:[26]

Particle Diameter	Weight Percent
> 50 μ	30-45
50 μ - 2 μ	30-40
< 2 μ	50-60

Although emissions from unpaved air strips were not measured, the basic emission factor (mass emitted per landing/take off cycle) and the correction factors can be approximated by the factors for unpaved roads.[26]

Agricultural tilling - The dust emitted by agricultural tilling (per acre of land tilled) is directly proportional to the silt content of the soil and the implement speed, and inversely proportional to the square of the surface moisture content.

$$e = \frac{1.4\ s\ (S/5.5)}{(PE/50)^2} \qquad (4)$$

where e = emission factor (lb/acre),

s = silt content of surface soil (%),

S = implement speed (mph), and

PE = Thornthwaite's precipitation-evaporation index.

The accuracy of the above equation in predicting the results of field testing of emissions from agricultural tilling is ± 15%.

On the average, the dust emissions from agricultural tilling can be separated into three size ranges, as follows:

Particle Diameter	Weight Percent
> 50 μ	5-25
50 μ - 2 μ	25-50
< 2 μ	30-40

Construction sites - The emission factor for medium-type construction activities (e.g., townhouses, shopping center) averages about 1.2 tons/acre/month. However, because of the use of water for dust control and interferences from other dust sources in the vicinity of the test sites, correlations between emission rate and potential correction parameters could not be established. There was strong evidence that the level of activity could change emissions by a factor of two or more.[26]

Aggregate storage piles - Total dust emissions from aggregate storage piles can be divided into the contributions of several distinct source activities which occur within the storage cycle:

- Loading of aggregate on to storage piles (12%)
- Equipment traffic in storage area (40%)
- Wind erosion (33%)
- Loadout of aggregate for shipment (15%)

The numbers in parentheses are the relative contributions of each activity to the total emissions.

The corrected emission factor which can be used to estimate the total amount of dust emissions with appreciable drift potential, i.e., particles smaller than 50 μ in diameter is given by the following expression.

$$e_{(\text{aggregate})} = \frac{0.33}{(PE/100)^2} \qquad (5)$$

where e = emission factor (lb/ton placed in storage), and

PE = Thornthwaite's precipitation evaporation index.

Mobile Sources

As mentioned on page 23, mobile sources were assumed to be uncontrolled sources of particulate pollutants. Estimates of nationwide emissions of particulates from mobile sources were taken from the recent EPA Data File of Nationwide Emissions.[9] The emission data in Ref. 9 are for the year 1971.

Particle size distribution data for emissions from mobile sources are meager and it was assumed that all particulate emissions were less than 7 μ in diameter. Table 25 presents the estimate of fine particulate emissions from mobile sources in 1971.

Table 25. ESTIMATED FINE PARTICLE EMISSIONS FROM MOBILE SOURCES, 1971[9]

Source	Fine Particle Emissions (10^6 tons/year)
Motor vehicles	
a. Gasoline	0.714
b. Diesel	0.046
Total for motor vehicle	0.760
Aircraft	0.047
Railroads	0.046
Vessels	0.051
Nonhighway use of motor fuels	
a. Farm tractors	0.029
b. Construction equipment	0.048
c. Snowmobiles	0.001
d. Small utility engines	0.002
e. Heavy duty general utility	0.028
Total for nonhighway use of motor fuels	0.108
TOTAL FOR MOBILE SOURCES	1.012

CHEMICAL COMPOSITION OF FINE PARTICULATES

Information on the chemical composition of particulates as a function of the particle size is very limited in scope. For most sources of interest, data are nonexistent. Although it was not possible to compile meaningful data on the variation of chemical composition with particle size, qualitative information on the types of potentially hazardous particulate pollutants that might be emitted from various industrial sources was obtained from Refs. 22 and 23.

Table 26 summarizes the information obtained on the types of potentially hazardous pollutants emitted from various industrial sources. Division of the sources in Table 26 into the broad categories of combustion, metallurgical, chemical, and mechanical processes can provide some indication of the size ranges in which most of the potentially hazardous material will be emitted. Metallurgical processes are generally characterized by a high percentage of fine metallic fumes which are formed from various high temperature reactions followed by condensation. Combustion and chemical processes form particulates varying widely in particle size depending upon input materials and reaction conditions. Particulates emitted from mechanical processes such as crushing and grinding and materials handling are predominately larger than 5 μ in size.

Table 26. PROFILE OF THE CHARACTERISTICS OF PARTICULATE POLLUTANTS EMITTED BY VARIOUS INDUSTRIAL SOURCES

Industry and/or Source	Type of Potentially Hazardous Particulate Pollutant Emitted
I. Stationary combustion	
A. Coal	
1. Electric utility	
a. Pulverized	Inorganic/metal oxides fluorides, polyorganics As, Ba, Be, B, Cr, Cu, Pb, Mn, Hg, Ni, Se, Sn, V, Zn
b. Stoker	As, Ba, Be, B, Cr, Cu, fluorides, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
c. Cyclone	As, Ba, Be, B, Cr, Cu, fluorides, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
2. Industrial	
a. Pulverized	As, Ba, Be, B, Cr, Cu, fluorides, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
b. Stoker	As, Ba, Be, B, Cr, Cu, fluorides, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
c. Cyclone	As, Ba, Be, B, Cr, Cu, Fluorides, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
3. Commercial and residential	As, Ba, Be, B, Cr, Cu, fluoride, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
B. Fuel Oil	
1. Electric utility and industrial	Inorganic/metal oxides, polyorganics, As, Ba, Be, Cr, Cu, Pb, Mn, Hg, Ni, Se, V, Zn

Table 26. (Continued) PROFILE OF THE CHARACTERISTICS OF PARTICULATE POLLUTANTS EMITTED BY VARIOUS INDUSTRIAL SOURCES

	Industry and/or Source	Type of Potentially Hazardous Particulate Pollutant Emitted
	2. Commercial and residential	Ba, Be, Cr, Cu, Pb, Mn, Hg, Ni, POM, Se, Sn, V, Zn
	C. Natural gas	
	1. Electric utility and industrial	———
	2. Commercial and residential	———
II.	Crushed stone	———
III.	Iron and steel	
	A. Sinter machines	Metal oxides, alkalies
	B. Open hearth furnace	Ba, Pb, Mn, Hg, Sn, V, Zn oxides, fluorides, POM
	C. Blast furnace	As, Cd, Mn, Hg, Ni, V, Zn oxides, fluorides, POM
	D. BOF	Ba, fluorides, Mn, Hg, POM, V, Zn
	E. Electric arc furnace	Ba, Mn, Hg, Zn
	F. Metallurgical coke	POM
IV.	Kraft pulp mills	
	A. Bark-fired boiler	———
	B. Recovery furnace	Cr, Hg, POM

Table 26. (Continued) PROFILE OF THE CHARACTERISTICS OF PARTICULATE POLLUTANTS EMITTED BY VARIOUS INDUSTRIAL SOURCES

	Industry and/or Source	Type of Potentially Hazardous Particulate Pollutant Emitted
	C. Lime kiln	———
V.	Cement plants, rotary kilns	Fluorides
VI.	Hot-mix asphalt plants	
	A. Rotary dryer	POM
VII.	Ferroalloys	
	A. Electric furnace	Mn, Ni, POM, V, Zn
	B. Blast furnace	Mn, Ni, Zn, O, POM
VIII.	Lime plants	
	A. Rotary kilns	———
IX.	Municipal incinerators	As, Cd, Cu, Pb, Hg, POM, Se, Zn
X.	Iron foundry cupolas	As, Ba, Be, Pb, Mn, Hg, Ni, V, Zn oxides, POM, fluorides
XI.	Primary copper	
	A. Roasting	As, Cd, Cu, fluoride Pb, Se
	B. Reverberatory furnace	As, Cd, Cu, fluoride, Pb, Se

Table 26. (Concluded) PROFILE OF THE CHARACTERISTICS OF PARTICULATE POLLUTANTS EMITTED BY VARIOUS INDUSTRIAL SOURCES

	Industry and/or Source	Type of Potentially Hazardous Particulate Pollutant Emitted
	C. Converters	As, Cd, Cu, fluoride, Pb, Se
	D. Material handling	As, Cd, Cu, fluoride, Pb, Se
XII.	Primary zinc	
	A. Roasting	As, Cd, Cu, fluorides, Pb, Se, Zn
	B. Sintering	Cd, fluorides, Pb, Zn
	C. Distillation	Cd, fluorides, Pb, Zn
XIII.	Primary lead	
	A. Sintering	As, Cd, fluorides, Pb, Se
	B. Blast furnace	As, Cd, fluorides, Pb, Se
XIV.	Primary aluminum	
	A. Reduction cells	Fluorides (gas and solid)
XV.	Iron ore pellet plant	Fluorides
XVI.	Asphalt roofing materials	POM
XVII.	Secondary copper	Cd, Cu, Pb, Zn, POM
XVIII.	Secondary lead	Pb
XIX.	Secondary zinc	Zn
XX.	Structural clay products	Fluorides

DETAILED EMISSION INVENTORIES FOR FINE PARTICULATES USING NATIONAL EMISSION DATA SYSTEM (NEDS)

This section describes the methodology for changes in EPA's National Emission Data System (NEDS) to include the capability to perform a detailed emission inventory of fine particulates for the United States and for selected geographical areas such as states or cities. The modifications to NEDS include incorporation of emission factors broken down on a particle size basis, supplementing or revising the data base as required and changing the output of the program.

The NEDS data bank includes a vast source of information on various pollution sources, source operating conditions, control equipment, usage and efficiency, source test data and emission rates. The NEDS data bank will provide an excellent base to perform a detailed inventory of the fine particulate emissions of the entire United States or any selected geographical area. Modifications to the NEDS which will be required to permit the calculation of fine particle emissions are described in the following subsections.

INTERFACE WITH NEDS SYSTEM

General

A flow diagram depicting the necessary modifications to the NEDS program is shown in Figure 2. These modifications should include:

1. Addition of an emission rate equation for fine particulates,
2. Addition of fractional efficiency data for each control device,
3. Addition of particle size distribution data for each process operation, and
4. Modification of output to include the calculated results for fine particulates.

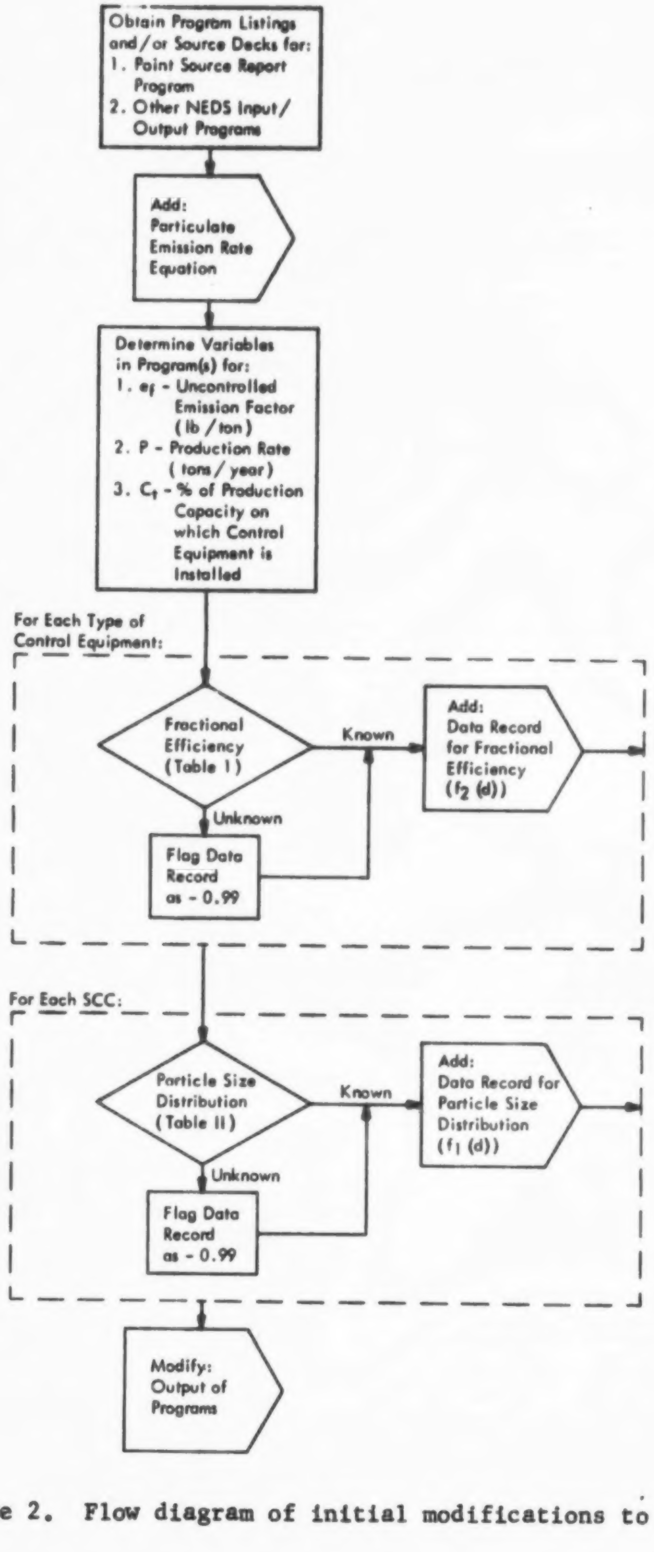

Obtain Program Listings and/or Source Decks for:
1. Point Source Report Program
2. Other NEDS Input/Output Programs
Add: Particulate Emission Rate Equation
Determine Variables in Program(s) for:
1. e_f - Uncontrolled Emission Factor (lb/ton)
2. P - Production Rate (tons/year)
3. C_t - % of Production Capacity on which Control Equipment is Installed
For Each Type of Control Equipment:
Fractional Efficiency (Table I)
Known
Add: Data Record for Fractional Efficiency (f_2 (d))
Unknown
Flag Data Record as - 0.99
For Each SCC:
Particle Size Distribution (Table II)
Known
Add: Data Record for Particle Size Distribution (f_1 (d))
Unknown
Flag Data Record as - 0.99
Modify: Output of Programs

Figure 2. Flow diagram of initial modifications to NEDS

The steps necessary to carry out each of the above changes are described next.

Input Requirements

Particulate Emission Rate Equation - The basic equation used to determine the quantity of fine particles emitted from a source is:

$$E_{d_1-d_2} = \frac{P\ e_f\ (C_t)}{2{,}000} \cdot f_1(d) , f_2(d) \qquad (6)$$

where

d = Particle size in microns.

$E_{d_1-d_2}$ = Emission rate of particles between d_1 and d_2, tons/year.

e_f = Emission factor (uncontrolled), pound/ton.

P = Production rate, tons/year.

C_t = Percentage of production capacity on which control equipment is installed (for each specific type of control device).

$f_1(d)$ = Particle size distribution of effluent.

$f_2(d)$ = Penetration (or 1 - the fractional efficiency) of the control system for specific particle sizes.

The specific particle size ranges (d_1-d_2) to be included in the inventory are:

E(1) = 3.00 - 7.00 μ
E(2) = 1.00 - 3.00 μ
E(3) = 0.50 - 1.00 μ
E(4) = 0.10 - 0.50 μ
E(5) = 0.05 - 0.10 μ
E(6) = 0.01 - 0.05 μ

The particulate emission rate equation should be added to the computer program and the program names for the variables e_f, P, and C_t should be identified.

A computer form of the emission rate equation for fine particulates might be constructed similar to the following Fortran statement:

$$E(I) = (P * EF * CT/2{,}000) * F1(I) * F2(I), \quad I = 1,6 \qquad (7)$$

The only variables in this equation not in NEDS at this time are F1(I) and F2(I).

Fractional Efficiency of Control Devices - A comparison of extrapolated fractional efficiency curves for some control devices is shown in Figure 1, page 17. Figure 1 is the basis for the values of fractional efficiencies shown in Table 27.

The identification numbers for specific control devices listed in Table 27 are those used in the NEDS program. As is clearly seen in Table 27, data on many of the control devices are not available. In these cases, an assumed or "flagged" value should be incorporated into the program (e.g., -0.99). Then, before this number is used in the particulate emission rate equation, the program can check it and skip the calculation (if = -0.99) for the various particle size ranges and print N.D. (for not determined) or leave blank.

All numbers not "flagged" can then be used in the emission rate equation for fine particulates after converting the fractional efficiencies to penetration, by the equation:

$$F2(I) = 1.0 - F3(I), \quad I = 1,6 \qquad (8)$$

where

F2(I) = Penetration of the control system at specified particle size.

F3(I) = Fractional efficiency of the control system at specified particle size.

Particle Size Distribution of Emitted Particulates - Table 28 gives available particle size distributions for various source operations. The values in the table have been converted from percentages to fractional values for direct use in the emission rate equation for fine particulates.

For each of the source operations indicated, the NEDS data bank may contain several Source Classification Codes (SCC). The SCC's for each source operation are shown in Table 29.

Table 27. FRACTIONAL EFFICIENCIES OF VARIOUS CONTROL SYSTEMS

Identification Number	Control Device/Method	Particle Size Range					
		3-7 μ	1-3 μ	0.5-1 μ	0.1-0.5 μ	0.05-0.1 μ	0.01-0.05 μ
000	No equipment	0	0	0	0	0	0
001	Wet scrubber--high efficiency	0.9997	0.91	0.74	0.38	0.08	0.02
002	--medium efficiency	0.98	0.79	0.57	0.26	0.05	0
003	--low efficiency	0.90	0.69	0.39	0.14	0.01	0
004	Gravity collector--high efficiency						
005	--medium efficiency						
006	--low efficiency						
007	Centrifugal collector--high efficiency	0.68	0.43	0.18	0.06	0	0
008	--medium efficiency	0.44	0.17	0.03	0.01	0	0
009	--low efficiency						
010	Electrostatic precipitator--high efficiency	0.991	0.984	0.977	0.962	0.945	0.918
011	--medium efficiency	0.93	0.89	0.83	0.71	0.59	0.45
012	--low efficiency	0.90	0.75	0.60	0.45	0.22	0.12
013	Gas scrubber						
014	Mist eliminator--high velocity						
015	--low velocity						
016	Fabric filter--high temperature	0.9999	0.995	0.982	0.967	0.958	0.956
017	--medium temperature						
018	--low temperature						
019	Catalytic afterburner						
020	Catalytic afterburner with heat exchanger						
021	Direct flame afterburner						
022	Direct flame afterburner with heat exchanger						
023	Flaring						
039	Catalytic oxidation--flue gas desulfurization						
040	Alkalized alumina						
041	Dry limestone injection						
042	Wet limestone injection						
043	Sulfuric acid plant--contact process						
044	--double contact process						
045	Sulfur plant						
046	Process change						
047	Vapor recovery system						
048	Activated carbon adsorption						
049	Liquid filtration system						

Source: Particulate Pollutant System Study, Volume II--Fine Particulate Emissions, NAPCA Contract No. CPA-22-69-104, Midwest Research Institute, pages 231-235, 1 August 1971 (updated 1973).

Table 28. PARTICLE SIZE DISTRIBUTION OF EFFLUENT OF VARIOUS SOURCE OPERATIONS

Source Operation	Particle Size Range					
	3-7 μ	1-3 μ	0.5-1 μ	0.1-0.5 μ	0.05-0.01 μ	0.01-0.05 μ
Asphalt dryers	0.190	0.131	0.022	0.0069	0.0001	0
Asphalt vent lines	0.232	0.0735	0.0041	0.0004	0	0
Cement kilns	0.165	0.103	0.0165	0.0054	0.0001	0
Ferroalloy electric furnaces producing ferrosilicon alloys	0.012	0.120	0.180	0.520	0.110	0.050
producing ferromanganese alloys	0.096	0.475	0.285	0.1343	0.0007	0
producing ferrochromium alloys	0.140	0.290	0.185	0.240	0.025	0.010
producing miscellaneous ferroalloys	0.095	0.295	0.230	0.315	0.026	0.009
Fertilizer granulators and dryers	0.040	0.0182	0.0043	0.0023	0.0002	0
Iron and steel, basic oxygen furnaces	0	0.060	0.360	0.578	0.002	0
electric arc furnaces	0.13	0.200	0.120	0.210	0.060	0.070
open hearth furnaces	0.013	0.102	0.230	0.590	0.052	0.008
sintering machine windbox	0.050	0.027	0.0056	0.0024	0	0
Iron foundry cupolas	0.065	0.060	0.020	0.0230	0.0035	0.0035
Kraft pulp mill bark-fired boilers	0.120	0.083	0.018	0.0086	0.0003	0.0001
recovery furnaces	0.150	0.440	0.240	0.138	0.0019	0.0001
lime kilns	0.055	0.0139	0.0009	0.0002	0	0
Lime plant rotary lime kilns	0.100	0.0850	0.030	0.0295	0.0033	0.0022
secondary sources	0.320	0.350	0.045	0.005	0	0
Municipal incinerators	0.050	0.075	0.035	0.045	0.010	0.015
Electric utility pulverized coal-fired boilers	0.160	0.100	0.021	0.0087	0.0002	0
stoker coal-fired boilers	0.180	0.048	0.009	0.0029	0	0
cyclone coal-fired boilers	0.250	0.220	0.055	0.0244	0.0005	0
Industrial pulverized coal-fired boilers	0.100	0.0195	0.0005	0	0	0
stoker coal-fired boilers	0.050	0.0176	0.0019	0.0005	0	0
cyclone coal-fired boilers	0.200	0.230	0.085	0.043	0.0016	0.0004
Electric utility and industrial gas-fired boilers	0	0.90	0	0	0	0
oil-fired boilers	0.90	0	0	0	0	0

Source: Particulate Pollutant System Study, Volume II--Fine Particle Emissions, NAPCA Contract No. CPA-22-69-104, Midwest Research Institute, pages 231-335, 1 August 1971 (Updated 1973).

Table 29. SOURCE CLASSIFICATION CODES

Asphalt dryers		
Asphaltic concrete	3-05-002-01	Rotary dryers
Asphalt vent lines		
Asphaltic concrete	3-05-002-02	Other sources
Cement kilns		
Cement manufacture, dry	3-05-006-01	Kilns
	3-05-006-03	Kilns--oil-fired
	3-05-006-04	Kilns--gas-fired
	3-05-006-05	Kilns--coal-fired
Cement manufacture, wet	3-05-007-01	Kilns
	3-05-007-03	Kilns--oil-fired
	3-05-007-04	Kilns--gas-fired
	3-05-007-05	Kilns--coal-fired
Ferroalloy electric furnaces		
a. Producing ferrosilicon alloys		
Ferroalloy open furnace	3-03-006-01	50% FeSi
	3-03-006-02	75% FeSi
	3-03-006-03	90% FeSi
	3-03-006-04	Silicon metal
b. Producing ferromanganese alloys		
Ferroalloy furnace	3-03-007-01	Ferromanganese
	3-03-006-05	Silicomanganese
c. Producing ferrochromium alloys		
Ferroalloy furnace	3-03-006-12	Low carbon Cr-reactor
d. Producing miscellaneous ferroalloys		
Ferroalloy furnace	3-03-007-02	General
	3-03-006-99	Other not classified

Table 29. (Continued)

Fertilizer granulators and dryers		
Fertilizer NH_4NO_3	3-01-027-04	Granulator--neutralizer
	3-01-027-05	Granulator
	3-01-027-06	Granulator--dry cooler
Fertilizer NSUPPHOS	3-01-028-01	Grind--dry
Fertilizer TRPSPHOS	3-01-029-02	Granular
Fertilizer DIAMPHOS	3-01-030-01	Dryer coolers
	3-01-030-02	Ammonia--granulate
Iron and steel		
a. Basic oxygen furnaces		
Steel production	3-03-009-03	BOF--General
b. Electric arc furnaces		
Steel production	3-03-009-04	Electric arc with lance
	3-03-009-05	Electric arc without lance
c. Open hearth furnaces		
Steel production	3-03-009-01	Open hearth with lance
	3-03-009-02	Open hearth without lance
d. Sintering machine windbox		
Iron production	3-03-008-03	Sintering--general
Iron foundry cupolas		
Gray iron	3-04-003-01	Cupola
Kraft pulp mill		
a. Bark-fired boilers	1-02-009-02	Boiler
b. Recovery furnaces		
Sulfate pulping	3-07-001-04	Recovery boiler
Sulfite pulping	3-07-002-01	Liquor recovering
c. Lime kilns		
Sulfate pulping	3-07-001-06	Lime kilns

Table 29. (Continued)

Lime plant		
a. Rotary lime kilns		
Lime manufacturing	3-05-016-04	Calcining--rotary kilns
b. Secondary sources		
Lime manufacturing	3-05-016-01	Primary crushing
	3-05-016-02	Secondary crushing
	3-05-016-94	Other not classified
Municipal incinerators		
Municipal incinerators	5-01-001-01	Multiple chamber
	5-01-001-02	Single chamber
Electric utility		
a. Pulverized coal-fired boilers		
Anthracite coal	1-01-001-01	> 100 MM BTU pulverized
	1-01-001-03	10-100 MM BTU pulverized
	1-01-001-05	< 10 MM BTU pulverized
Bituminous coal	1-01-002-01	> 100 MM BTU pulverized wet
	1-01-002-02	> 100 MM BTU pulverized dry
	1-01-002-06	10-100 MM BTU pulverized wet
	1-01-002-07	10-100 MM BTU pulverized dry
	1-01-002-12	< 10 MM BTU pulverized dry
Lignite	1-01-003-01	> 100 MM BTU pulverized wet
	1-01-003-02	> 100 MM BTU pulverized dry
	1-01-003-07	10-100 MM BTU pulverized dry
	1-01-003-08	10-100 MM BTU pulverized wet
	1-01-003-12	< 10 MM BTU pulverized dry
b. Stoker coal-fired boilers		
Anthracite coal	1-01-001-02	> 100 MM BTU stoker
	1-01-001-04	10-100 MM BTU stoker
	1-01-001-06	< 10 MM BTU stoker
Bituminous coal	1-01-002-04	> 100 MM BTU SPD stoker
	1-01-002-05	> 100 MM BTU OF stoker
	1-01-002-08	10-100 MM BTU OF stoker

Table 29. (Continued)

b. **Stoker coal-fired boilers** (concluded)		
Bituminous coal (concluded)	1-01-002-09	10-100 MM BTU UF stoker
	1-01-002-10	< 10 MM BTU OF stoker
	1-01-002-11	< 10 MM BTU UF stoker
Lignite	1-01-003-04	> 100 MM BTU OF stoker
	1-01-003-05	> 100 MM BTU UF stoker
	1-01-003-06	> 100 MM BTU SPD stoker
	1-01-003-09	10-100 MM BTU OF stoker
	1-01-003-10	10-100 MM BTU UF stoker
	1-01-003-11	10-100 MM BTU SPD stoker
	1-01-003-13	< 10 MM BTU OF stoker
	1-01-003-14	< 10 MM BTU UF stoker
	1-01-003-15	< 10 MM BTU SPD stoker
c. **Cyclone coal-fired boilers**		
Bituminous coal	1-01-002-03	> 100 MM BTU cyclone
Lignite	1-01-003-03	> 100 MM BTU cyclone
d. **Gas-fired boilers**		
Natural gas	1-01-006-01	> 100 MM BTU/hr
	1-01-006-02	10-100 MM BTU/hr
	1-01-006-03	< 10 MM BTU/hr
Process gas	1-01-007-01	> 100 MM BTU/hr
	1-01-007-02	10-100 MM BTU/hr
	1-01-007-03	< 10 MM BTU/hr
e. **Oil-fired boilers**		
Residual oil	1-01-004-01	> 100 MM BTU/hr
	1-01-004-02	10-100 MM BTU/hr
	1-01-004-03	< 10 MM BTU/hr
Distillate oil	1-01-005-01	> 100 MM BTU/hr
	1-01-005-02	10-100 MM BTU/hr
	1-01-005-03	< 10 MM BTU/hr
Industrial		
a. **Pulverized coal-fired boilers**		
Anthracite coal	1-02-001-01	> 100 MM BTU/hr pulverized
	1-02-001-03	10-100 MM BTU pulverized

Table 29. (Continued)

Industrial (continued)

a. Pulverized coal-fired boilers (concluded)

Anthracite coal (concluded)	1-02-001-05	< 10 MM BTU/hr pulverized
Bituminous coal	1-02-002-01	> 100 MM BTU pulverized wet
	1-02-002-02	> 100 MM BTU pulverized dry
	1-02-002-07	10-100 MM BTU pulverized wet
	1-02-002-08	10-100 MM BTU pulverized dry
	1-02-002-12	< 10 MM BTU pulverized dry
Lignite	1-02-003-01	> 100 MM BTU pulverized wet
	1-02-003-02	> 100 MM BTU pulverized dry
	1-02-003-07	10-100 MM BTU pulverized dry
	1-02-003-08	10-100 MM BTU pulverized wet
	1-02-003-12	< 10 MM BTU pulverized dry

b. Stoker coal-fired boilers

Anthracite coal	1-02-001-02	> 100 MM BTU/hr stoker
	1-02-001-04	10-100 MM BTU stoker
	1-02-001-06	< 10 MM BTU/hr stoker
Bituminous coal	1-02-002-04	> 100 MM BTU SPD stoker
	1-02-002-05	10-100 MM BTU OF stoker
	1-02-002-06	10-100 MM BTU UF stoker
	1-02-002-09	10-100 MM BTU SPD stoker
	1-02-002-10	< 10 MM BTU OFD stoker
	1-02-002-11	< 10 MM BTU UFD stoker
	1-02-002-13	< 10 MM BTU SPD stoker
Lignite	1-02-003-04	> 100 MM BTU OF stoker
	1-02-003-05	> 100 MM BTU UF stoker
	1-02-003-06	> 100 MM BTU SPD stoker
	1-02-003-09	10-100 MM BUT OF stoker
	1-02-003-10	10-100 MM BUT UF stoker
	1-02-003-11	10-100 MM BUT SPD stoker
	1-02-003-13	< 10 MM BUT OF stoker
	1-02-003-14	< 10 MM BUT UF stoker
	1-02-003-16	< 10 MM BUT SPD stoker

c. Cyclone coal-fired boilers

Bituminous coal	1-02-002-03	> 100 MM BTU cyclone
Lignite	1-02-003-03	> 100 MM BTU cyclone

Table 29. (Concluded)

d. Gas-fired boilers		
Natural gas	1-02-006-01	> 100 MM BTU/hr
	1-02-006-02	10-100 BTU/hr
	1-02-006-03	< 10 MM BTU/hr
Process gas	1-02-007-01	> 100 MM BTU/hr
	1-02-007-02	10-100 MM BTU/hr
	1-02-007-03	< 10 MM BTU/hr
Liquid petroleum gas	1-02-010-02	10-100 MM BTU/hr
	1-02-010-03	< 10 MM BTU/hr
e. Oil-fired boilers		
Residual oil	1-02-004-01	> 100 MM BTU/hr
	1-02-004-02	10-100 MM BTU/hr
	1-02-004-03	< 10 MM BTU/hr
Distillate oil	1-02-005-01	> 100 MM BTU/hr
	1-02-005-02	10-100 MM BTU/hr
	1-02-005-03	< 10 MM BTU/hr

In order to use Tables 28 and 29 efficiently, the following steps are needed to incorporate this data in the system:

a. Determine if the SCC is listed in Table 29.

b. If the SCC code is listed, then use the data given in Table 28 for the source operation of Table 29 as values for F2(I), I = 1,6.

c. If the SCC is not listed, then assume a value = -0.99 as the values of F2(I), I = 1,6.

All numbers not "flagged" (i.e., not equal to -0.99) can then be used directly in the emission rate equation for fine particulates. If a flagged value is found, then the values for the various particle size ranges will not be computed, but will be output as N.D. (not determined) or left blank.

Output Modifications

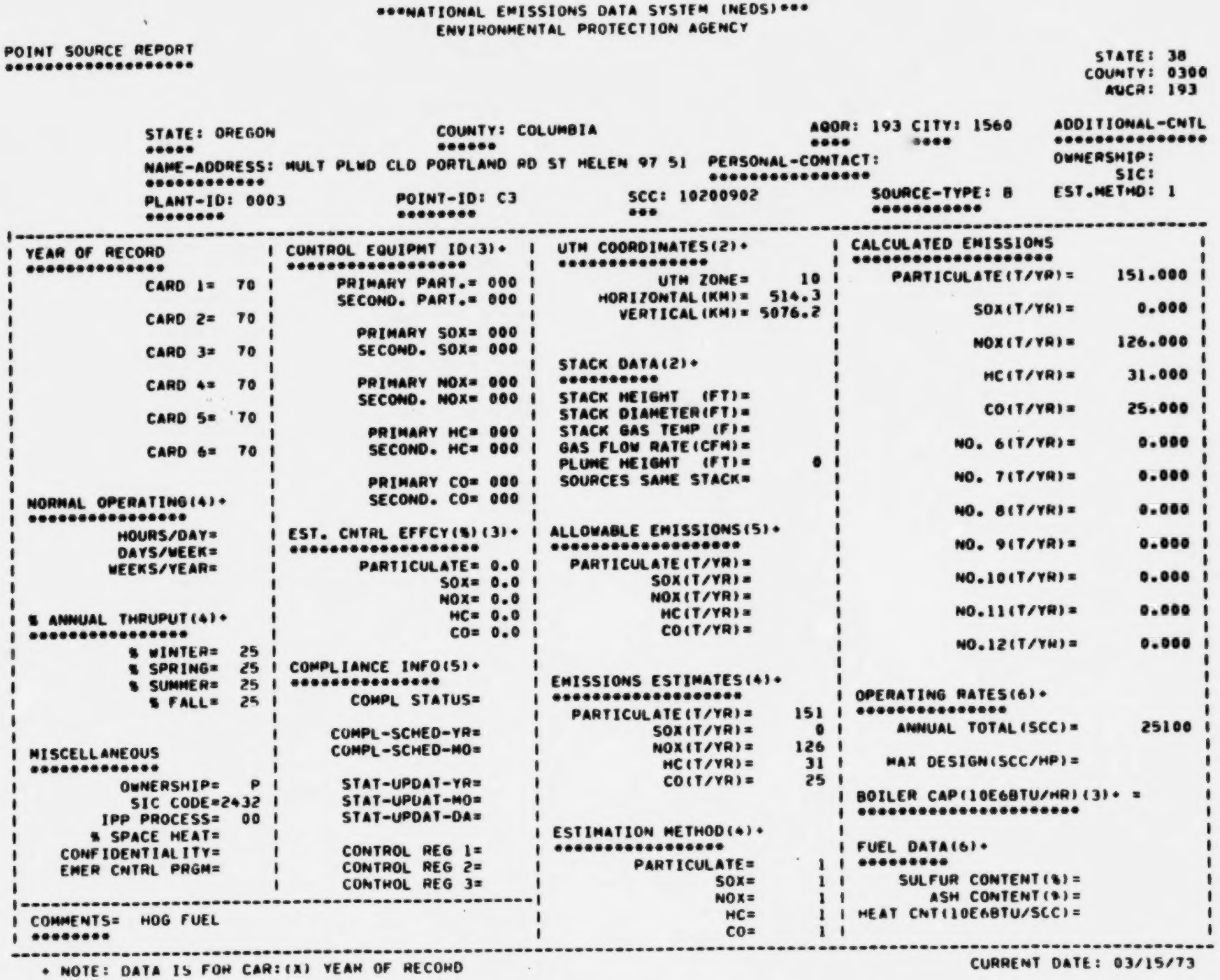
Figure 3 shows output from the Point Source Report Program. Space for expansion has been included and additions are easily made.

The "Calculated Emission" section could be changed to include something similar to that shown in Figure 4. Below the particulate emissions (tons/year) column, the emissions for the various particle size ranges could be added. Space would still remain in this section to single space the gaseous emissions data.

Data Gaps and Continued Modifications

The NEDS programs have included a wide range of sources and control equipment types for which particle size distribution or fractional efficiency data have not been sufficiently determined to date. Also, many of the entry dates for the original data in NEDS are in the 1969-1971 time period. Since that time period plant openings and shutdowns have occurred in several industries. A notable example is the continuing decline in the number of operational open hearth furnaces in the steel industry. Therefore, the extent to which the NEDS data base actually depicts current operational status in several industries should be checked.

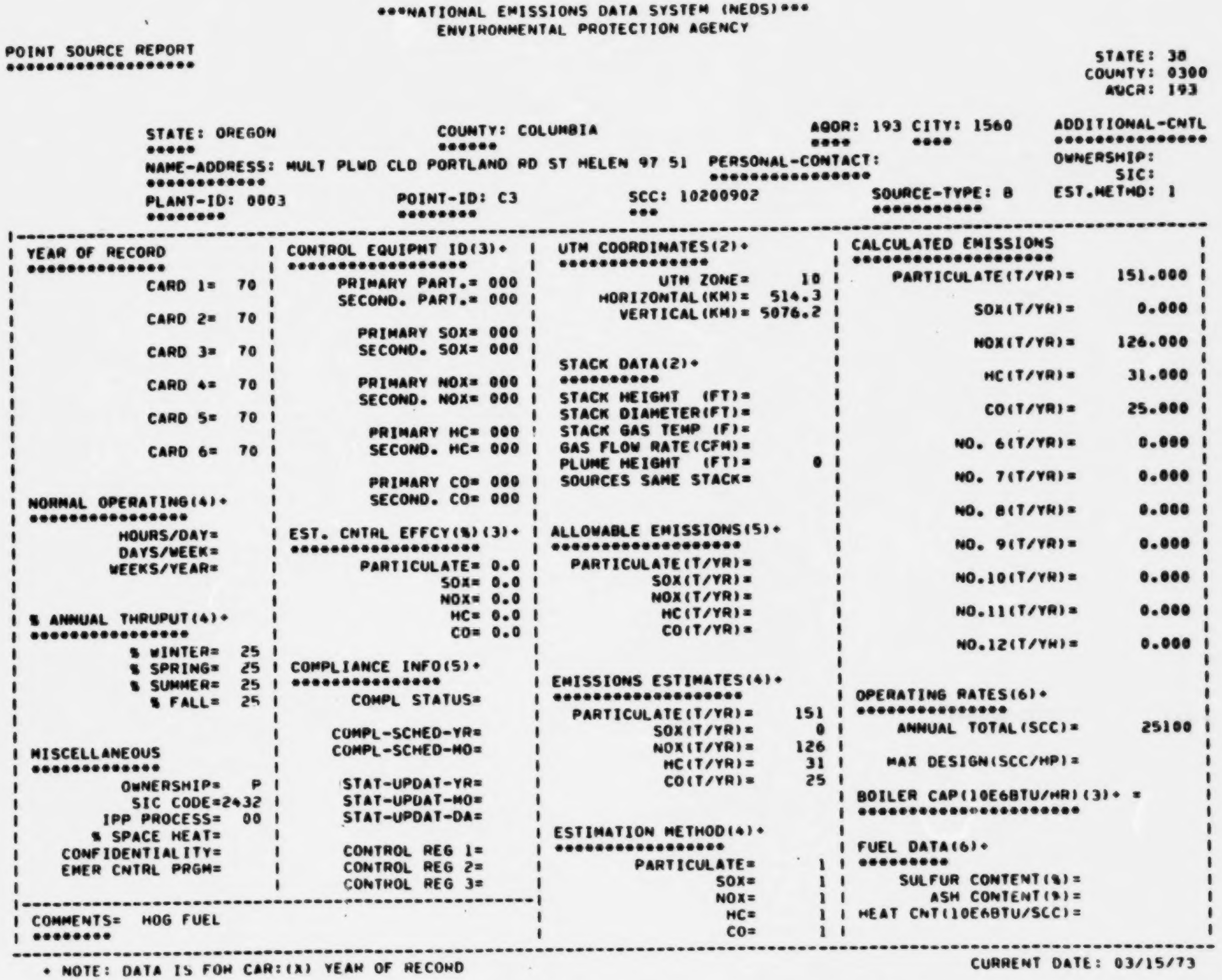
The incorporation of new data into the system can be easily accomplished. Information on data gaps or new data can be entered into the system as shown in the simplified flow diagram given in Figure 5.



```
                                   ***NATIONAL EMISSIONS DATA SYSTEM (NEDS)***
                                        ENVIRONMENTAL PROTECTION AGENCY
POINT SOURCE REPORT
*******************                                                                                  STATE: 38
                                                                                                    COUNTY: 0300
                                                                                                      AQCR: 193

              STATE: OREGON                  COUNTY: COLUMBIA                    AQCR: 193 CITY: 1560   ADDITIONAL-CNTL
              *****                          ******                              ****      ****         ***************
              NAME-ADDRESS: MULT PLWD CLD PORTLAND RD ST HELEN 97 51  PERSONAL-CONTACT:                 OWNERSHIP:
              ************                                            ****************                        SIC:
              PLANT-ID: 0003              POINT-ID: C3           SCC: 10200902            SOURCE-TYPE: B   EST.METHD: 1
              ********                    ********               ***                      ***********
|------------------------------------------------------------------------------------------------------------------------|
| YEAR OF RECORD                | CONTROL EQUIPMT ID(3)+   | UTM COORDINATES(2)+           | CALCULATED EMISSIONS            |
| **************                | ******************       | ***************               | ********************            |
|                  CARD 1=  70  |      PRIMARY PART.= 000  |             UTM ZONE=     10  |    PARTICULATE(T/YR)=   151.000  |
|                               |      SECOND. PART.= 000  |       HORIZONTAL(KM)=  514.3  |                                 |
|                  CARD 2=  70  |                          |         VERTICAL(KM)= 5076.2  |             SOX(T/YR)=     0.000  |
|                               |       PRIMARY SOX= 000   |                               |                                 |
|                  CARD 3=  70  |       SECOND. SOX= 000   |                               |             NOX(T/YR)=   126.000  |
|                               |                          | STACK DATA(2)+                |                                 |
|                  CARD 4=  70  |       PRIMARY NOX= 000   | **********                    |              HC(T/YR)=    31.000  |
|                               |       SECOND. NOX= 000   | STACK HEIGHT   (FT)=          |                                 |
|                  CARD 5=  70  |                          | STACK DIAMETER(FT)=           |              CO(T/YR)=    25.000  |
|                               |        PRIMARY HC= 000   | STACK GAS TEMP (F)=           |                                 |
|                  CARD 6=  70  |        SECOND. HC= 000   | GAS FLOW RATE(CFM)=           |         NO. 6(T/YR)=      0.000  |
|                               |                          | PLUME HEIGHT   (FT)=       0  |                                 |
|                               |        PRIMARY CO= 000   | SOURCES SAME STACK=           |         NO. 7(T/YR)=      0.000  |
| NORMAL OPERATING(4)+          |        SECOND. CO= 000   |                               |                                 |
| ****************              |                          |                               |         NO. 8(T/YR)=      0.000  |
|                HOURS/DAY=     | EST. CNTRL EFFCY(%)(3)+  | ALLOWABLE EMISSIONS(5)+       |                                 |
|                DAYS/WEEK=     | *******************      | *******************           |         NO. 9(T/YR)=      0.000  |
|               WEEKS/YEAR=     |      PARTICULATE= 0.0    |    PARTICULATE(T/YR)=         |                                 |
|                               |              SOX= 0.0    |            SOX(T/YR)=         |         NO.10(T/YR)=      0.000  |
|                               |              NOX= 0.0    |            NOX(T/YR)=         |                                 |
| % ANNUAL THRUPUT(4)+          |               HC= 0.0    |             HC(T/YR)=         |         NO.11(T/YR)=      0.000  |
| ****************              |               CO= 0.0    |             CO(T/YR)=         |                                 |
|                % WINTER=  25  |                          |                               |         NO.12(T/YR)=      0.000  |
|                % SPRING=  25  | COMPLIANCE INFO(5)+      |                               |                                 |
|                % SUMMER=  25  | ***************          | EMISSIONS ESTIMATES(4)+       |                                 |
|                  % FALL=  25  |      COMPL STATUS=       | *******************           | OPERATING RATES(6)+             |
|                               |                          |    PARTICULATE(T/YR)=    151  | ***************                 |
|                               |     COMPL-SCHED-YR=      |            SOX(T/YR)=      0  |    ANNUAL TOTAL(SCC)=    25100  |
| MISCELLANEOUS                 |     COMPL-SCHED-MO=      |            NOX(T/YR)=    126  |                                 |
| *************                 |                          |             HC(T/YR)=     31  |    MAX DESIGN(SCC/HR)=          |
|              OWNERSHIP=   P   |     STAT-UPDAT-YR=       |             CO(T/YR)=     25  |                                 |
|              SIC CODE=2432   |     STAT-UPDAT-MO=       |                               | BOILER CAP(10E6BTU/HR)(3)+ =    |
|            IPP PROCESS=  00   |     STAT-UPDAT-DA=       |                               | *********************           |
|           % SPACE HEAT=       |                          | ESTIMATION METHOD(4)+         |                                 |
|       CONFIDENTIALITY=        |     CONTROL REG 1=       | ****************              | FUEL DATA(6)+                   |
|       EMER CNTRL PRGM=        |     CONTROL REG 2=       |           PARTICULATE=     1  | *********                       |
|                               |     CONTROL REG 3=       |                   SOX=     1  |     SULFUR CONTENT(%)=          |
|----------------------------------------------------------|                   NOX=     1  |        ASH CONTENT(%)=          |
| COMMENTS=  HOG FUEL                                      |                    HC=     1  | HEAT CNT(10E6BTU/SCC)=          |
| ********                                                 |                    CO=     1  |                                 |
|------------------------------------------------------------------------------------------------------------------------|
  + NOTE: DATA IS FOR CAR:(X) YEAR OF RECORD                                                  CURRENT DATE: 03/15/73
```

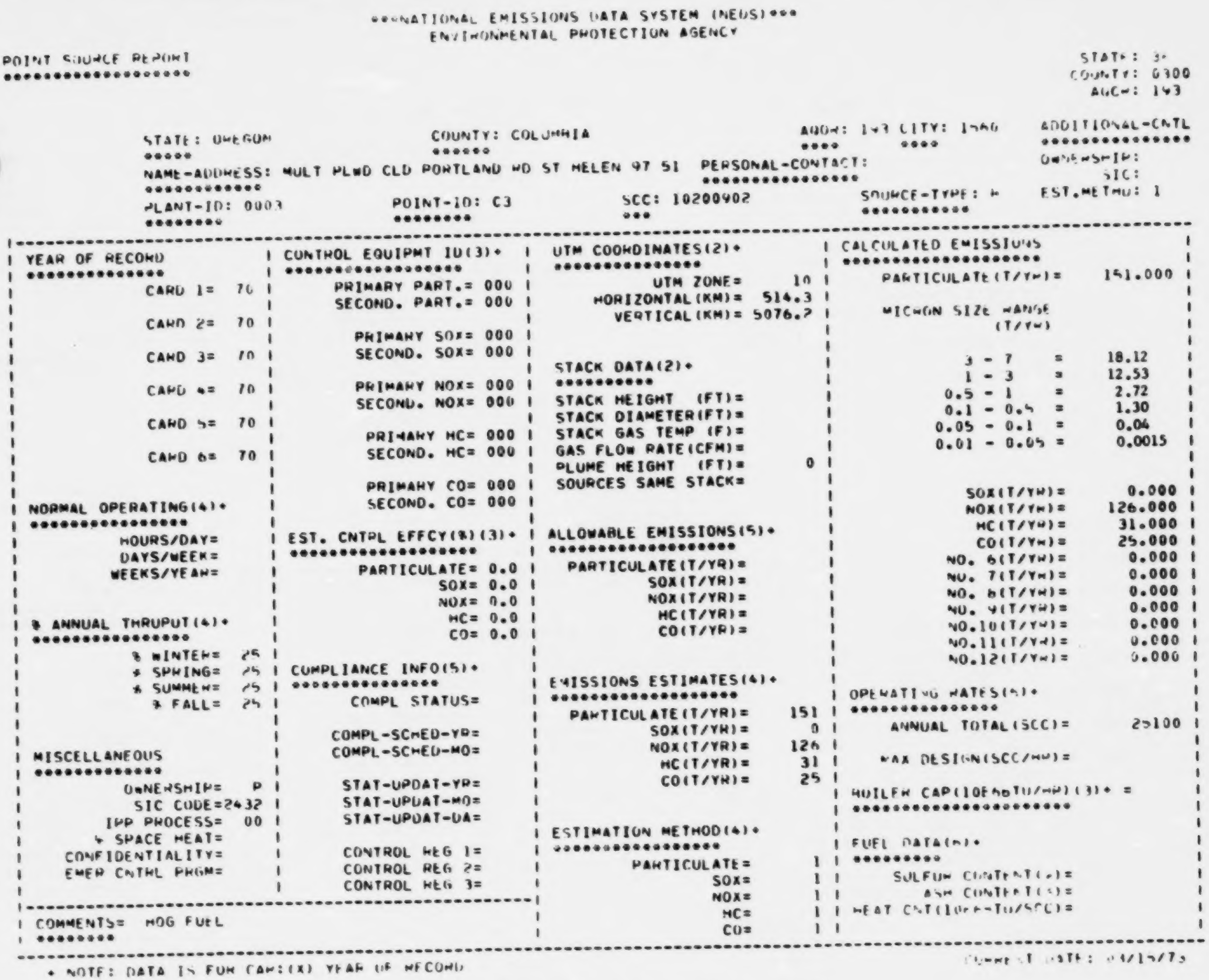
Figure 3. Example of current output from NEDS



```
                                   ***NATIONAL EMISSIONS DATA SYSTEM (NEDS)***
                                         ENVIRONMENTAL PROTECTION AGENCY
POINT SOURCE REPORT
*******************                                                                                          STATE: 38
                                                                                                           COUNTY: 0300
                                                                                                             AVCR: 193

          STATE: OREGON               COUNTY: COLUMBIA                          AQOR: 193 CITY: 1560    ADDITIONAL-CNTL
          *****                       ******                                    ****      ****          ***************
          NAME-ADDRESS: MULT PLWD CLD PORTLAND RD ST HELEN 97 51  PERSONAL-CONTACT:                     OWNERSHIP:
          ************                                            ****************                            SIC:
          PLANT-ID: 0003           POINT-ID: C3             SCC: 10200902             SOURCE-TYPE: B    EST.METHD: 1
          ********                 ********                 ***                       ***********
|------------------------------------------------------------------------------------------------------------------|
| YEAR OF RECORD          | CONTROL EQUIPMNT ID(3)+  | UTM COORDINATES(2)+         | CALCULATED EMISSIONS                 |
| **************          | ******************       | ***************             | ********************                 |
|             CARD 1=  70 |     PRIMARY PART.= 000   |              UTM ZONE=   10 |    PARTICULATE(T/YR)=     151.000    |
|                         |     SECOND. PART.= 000   |      HORIZONTAL(KM)=  514.3 |                                      |
|             CARD 2=  70 |                          |        VERTICAL(KM)= 5076.2 |            SOX(T/YR)=       0.000    |
|                         |       PRIMARY SOX= 000   |                             |                                      |
|             CARD 3=  70 |       SECOND. SOX= 000   |                             |            NOX(T/YR)=     126.000    |
|                         |                          | STACK DATA(2)+              |                                      |
|             CARD 4=  70 |       PRIMARY NOX= 000   | **********                  |             HC(T/YR)=      31.000    |
|                         |       SECOND. NOX= 000   | STACK HEIGHT  (FT)=         |                                      |
|             CARD 5=  70 |                          | STACK DIAMETER(FT)=         |             CO(T/YR)=      25.000    |
|                         |        PRIMARY HC= 000   ! STACK GAS TEMP (F)=         |                                      |
|             CARD 6=  70 |        SECOND. HC= 000   | GAS FLOW RATE(CFM)=         |          NO. 6(T/YR)=       0.000    |
|                         |                          | PLUME HEIGHT  (FT)=       0 |                                      |
|                         |        PRIMARY CO= 000   | SOURCES SAME STACK=         |          NO. 7(T/YR)=       0.000    |
| NORMAL OPERATING(4)+    |        SECOND. CO= 000   |                             |                                      |
| ****************        |                          |                             |          NO. 8(T/YR)=       0.000    |
|          HOURS/DAY=     | EST. CNTRL EFFCY(%)(3)+  | ALLOWABLE EMISSIONS(5)+     |                                      |
|          DAYS/WEEK=     | *******************      | *******************         |          NO. 9(T/YR)=       0.000    |
|         WEEKS/YEAR=     |        PARTICULATE= 0.0  |   PARTICULATE(T/YR)=        |                                      |
|                         |                SOX= 0.0  |           SOX(T/YR)=        |          NO.10(T/YR)=       0.000    |
|                         |                NOX= 0.0  |           NOX(T/YR)=        |                                      |
| % ANNUAL THRUPUT(4)+    |                 HC= 0.0  |            HC(T/YR)=        |          NO.11(T/YR)=       0.000    |
| ****************        |                 CO= 0.0  |            CO(T/YR)=        |                                      |
|          % WINTER=  25  |                          |                             |          NO.12(T/YH)=       0.000    |
|          % SPRING=  25  | COMPLIANCE INFO(5)+      |                             |                                      |
|          % SUMMER=  25  | ***************          | EMISSIONS ESTIMATES(4)+     |                                      |
|            % FALL=  25  |      COMPL STATUS=       | *******************         | OPERATING RATES(6)+                  |
|                         |                          |   PARTICULATE(T/YR)=    151 | ***************                      |
|                         |    COMPL-SCHED-YR=       |           SOX(T/YR)=      0 |     ANNUAL TOTAL(SCC)=       25100   |
| MISCELLANEOUS           |    COMPL-SCHED-MO=       |           NOX(T/YR)=    126 |                                      |
| *************           |                          |            HC(T/YR)=     31 |    MAX DESIGN(SCC/HP)=               |
|         OWNERSHIP=   P  |     STAT-UPDAT-YR=       |            CO(T/YR)=     25 |                                      |
|         SIC CODE=2432   |     STAT-UPDAT-MO=       |                             | BOILER CAP(10E6BTU/HR)(3)+ =         |
|      IPP PROCESS=  00   |     STAT-UPDAT-DA=       |                             | *********************                |
|     % SPACE HEAT=       |                          | ESTIMATION METHOD(4)+       |                                      |
|  CONFIDENTIALITY=       |     CONTROL REG 1=       | *****************           | FUEL DATA(6)+                        |
|  EMER CNTRL PRGM=       |     CONTROL REG 2=       |         PARTICULATE=      1 | *********                            |
|                         |     CONTROL REG 3=       |                 SOX=      1 |     SULFUR CONTENT(%)=               |
|----------------------------------------------------|                 NOX=      1 |        ASH CONTENT(%)=               |
| COMMENTS=  HOG FUEL                                |                  HC=      1 | HEAT CNT(10E6BTU/SCC)=               |
| ********                                           |                  CO=      1 |                                      |
--------------------------------------------------------------------------------------------------------------------
   + NOTE: DATA IS FOR CAR:(X) YEAR OF RECORD                                           CURRENT DATE: 03/15/73
```

Figure 3. Example of current output from NEDS



```
                              ***NATIONAL EMISSIONS DATA SYSTEM (NEDS)***
                                    ENVIRONMENTAL PROTECTION AGENCY
POINT SOURCE REPORT                                                                              STATE: 38
*******************                                                                             COUNTY: 0300
                                                                                                  AQCR: 193

          STATE: OREGON              COUNTY: COLUMBIA                    AQCR: 193 CITY: 1560   ADDITIONAL-CNTL
          *****                      ******                              ****      ****         ***************
          NAME-ADDRESS: MULT PLWD CLD PORTLAND RD ST HELEN 97 51  PERSONAL-CONTACT:             OWNERSHIP:
          ************                                            ****************                    SIC:
          PLANT-ID: 0003             POINT-ID: C3          SCC: 10200902          SOURCE-TYPE: B   EST.METHD: 1
          ********                   ********              ***                    ***********
|-----------------------------------------------------------------------------------------------------------
| YEAR OF RECORD            | CONTROL EQUIPMT ID(3)*  | UTM COORDINATES(2)*          | CALCULATED EMISSIONS         |
| **************            | ******************      | ***************              | ********************         |
|             CARD 1=  70   |    PRIMARY PART.= 000   |            UTM ZONE=     10  |    PARTICULATE(T/YR)=  151.000 |
|                           |    SECOND. PART.= 000   |     HORIZONTAL(KM)=  514.3   |                              |
|             CARD 2=  70   |                         |       VERTICAL(KM)= 5076.2   |    MICRON SIZE RANGE         |
|                           |      PRIMARY SOX= 000   |                              |          (T/YR)              |
|             CARD 3=  70   |      SECOND. SOX= 000   |                              |                              |
|                           |                         | STACK DATA(2)*               |          3 - 7    =    18.12 |
|             CARD 4=  70   |      PRIMARY NOX= 000   | **********                   |          1 - 3    =    12.53 |
|                           |      SECOND. NOX= 000   | STACK HEIGHT   (FT)=         |        0.5 - 1    =     2.72 |
|             CARD 5=  70   |                         | STACK DIAMETER(FT)=          |        0.1 - 0.5  =     1.30 |
|                           |       PRIMARY HC= 000   | STACK GAS TEMP (F)=          |       0.05 - 0.1  =     0.04 |
|             CARD 6=  70   |       SECOND. HC= 000   | GAS FLOW RATE(CFM)=          |       0.01 - 0.05 =   0.0015 |
|                           |                         | PLUME HEIGHT   (FT)=       0 |                              |
|                           |       PRIMARY CO= 000   | SOURCES SAME STACK=          |                              |
| NORMAL OPERATING(4)*      |       SECOND. CO= 000   |                              |            SOX(T/YR)=    0.000 |
| ****************          |                         |                              |            NOX(T/YR)=  126.000 |
|          HOURS/DAY=       | EST. CNTPL EFFCY(%)(3)* | ALLOWABLE EMISSIONS(5)*      |             HC(T/YR)=   31.000 |
|          DAYS/WEEK=       | ********************    | ********************         |             CO(T/YR)=   25.000 |
|         WEEKS/YEAR=       |      PARTICULATE= 0.0   |   PARTICULATE(T/YR)=         |         NO. 6(T/YR)=    0.000 |
|                           |              SOX= 0.0   |           SOX(T/YR)=         |         NO. 7(T/YR)=    0.000 |
|                           |              NOX= 0.0   |           NOX(T/YR)=         |         NO. 8(T/YR)=    0.000 |
| % ANNUAL THRUPUT(4)*      |               HC= 0.0   |            HC(T/YR)=         |         NO. 9(T/YR)=    0.000 |
| ****************          |               CO= 0.0   |            CO(T/YR)=         |         NO.10(T/YR)=    0.000 |
|          % WINTER=  25    |                         |                              |         NO.11(T/YR)=    0.000 |
|          % SPRING=  25    | COMPLIANCE INFO(5)*     |                              |         NO.12(T/YR)=    0.000 |
|          % SUMMER=  25    | ***************         | EMISSIONS ESTIMATES(4)*      |                              |
|            % FALL=  25    |     COMPL STATUS=       | ********************         | OPERATING RATES(5)*          |
|                           |                         |   PARTICULATE(T/YR)=     151 | ***************              |
|                           |    COMPL-SCHED-YR=      |           SOX(T/YR)=       0 |     ANNUAL TOTAL(SCC)=    25100 |
| MISCELLANEOUS             |    COMPL-SCHED-MO=      |           NOX(T/YR)=     126 |                              |
| *************             |                         |            HC(T/YR)=      31 |     MAX DESIGN(SCC/HR)=      |
|          OWNERSHIP=   P   |    STAT-UPDAT-YR=       |            CO(T/YR)=      25 |                              |
|          SIC CODE=2432    |    STAT-UPDAT-MO=       |                              | BOILER CAP(10E6BTU/HR)(3)* = |
|        IPP PROCESS=  00   |    STAT-UPDAT-DA=       |                              | **********************       |
|       % SPACE HEAT=       |                         | ESTIMATION METHOD(4)*        |                              |
|    CONFIDENTIALITY=       |    CONTROL REG 1=       | *****************            | FUEL DATA(6)*                |
|    EMER CNTRL PRGM=       |    CONTROL REG 2=       |        PARTICULATE=        1 | *********                    |
|                           |    CONTROL REG 3=       |                SOX=        1 |     SULFUR CONTENT(%)=       |
|---------------------------------------------------|                NOX=        1 |        ASH CONTENT(%)=       |
| COMMENTS=  HOG FUEL                               |                 HC=        1 | HEAT CNT(10E6BTU/SCC)=       |
| ********                                          |                 CO=        1 |                              |
-------------------------------------------------------------------------------------------------------------
   * NOTE: DATA IS FOR CARD(X) YEAR OF RECORD                                       CURRENT DATE: 04/15/75
```

Figure 4. Example of modified output from NEDS

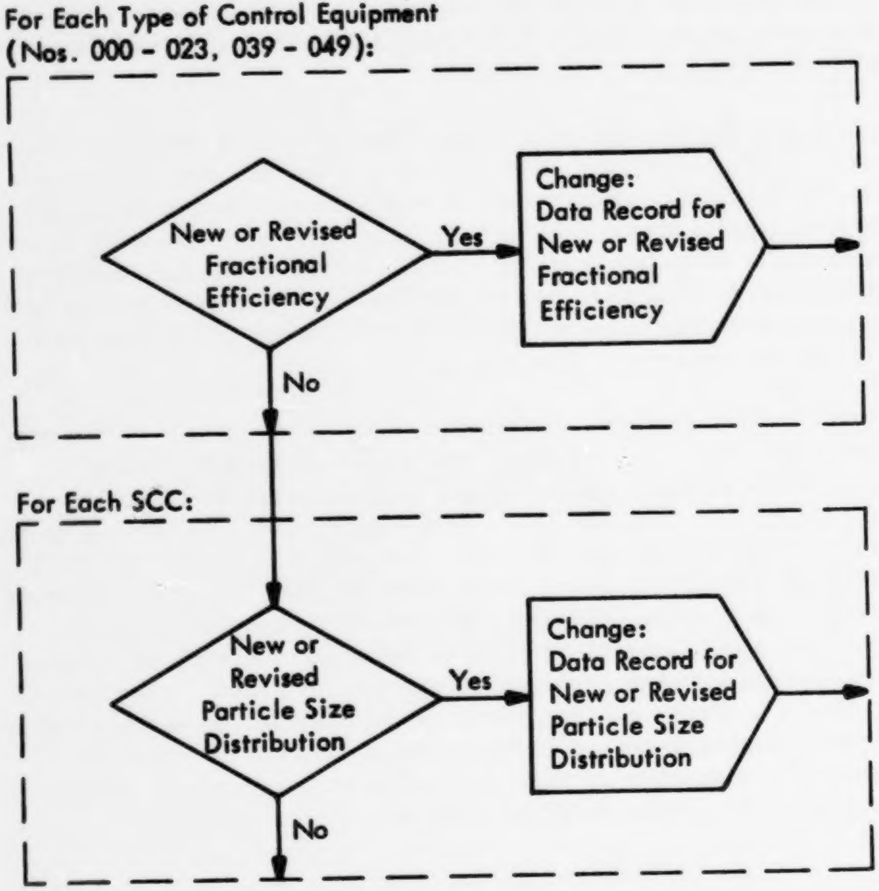

For Each Type of Control Equipment
(Nos. 000 - 023, 039 - 049):
New or Revised Fractional Efficiency
Yes
Change: Data Record for New or Revised Fractional Efficiency
No
For Each SCC:
New or Revised Particle Size Distribution
Yes
Change: Data Record for New or Revised Particle Size Distribution
No

Figure 5. Simplified flow diagram of continuing data additions and modifications to NEDS

DETAILED EMISSION INVENTORIES FOR SPECIFIC GEOGRAPHIC REGIONS

The NEDS data bank with the modifications outlined in the preceding sections can be used to develop detailed emission inventories for various geographic regions. Two examples that might be of interest are: (1) a more detailed inventory of the entire United States, and (2) inventories of cities which represent a spectrum ranging from those having a severe fine particle problem to those with a typical situation. Brief comments on each of these examples are given next.

Emission Inventory for the United States - The NEDS data bank contains more extensive information on specific sources than was used to prepare the emission inventory in this report, and the computational procedures outlined in the modifications to the NEDS data bank could be used to refine the nationwide emission inventory of fine particulates. However, the full potential of NEDS will not be realized until the many data gaps in both particle size distribution data and fractional efficiency of control devices are filled.

Inventory for Specific Cities - Currently, NEDS cannot retrieve summary data on individual cities; the lowest geographical area NEDS can presently deal with is the county. Hence to accomplish an inventory of specific cities, the existing NEDS retrieval program would have to be modified to retrieve on the city ID code (see Figure 3, page 73) which should be entered for all cities greater than 25,000. Moreover, because of the way the NEDS program operates, this would be most efficiently achieved by first specifying the county or counties the city is located in, and then sorting through each record therein to select those having the proper city ID. With this additional modification and assuming that the basic NEDS contains detailed information on sources in specific cities, emission inventories of fine particulates for various cities could be developed using the modified NEDS data bank.[25]

Four cities that might be used to develop a profile ranging from a bad or severe fine particle problem to a typical situation are:

1. Gary, Indiana - representing a city with a severe problem.

2. St. Louis, Missouri - representing a city with a medium problem. St. Louis was also selected because the ongoing RAPS program will generate a comprehensive data base for the city.

3. Minneapolis, Minnesota - representing a city with a typical urban pollution situation.

4. Columbus, Ohio - representing a city with relatively "clean" air.

The computational procedures outlined in the modifications to the NEDS data bank could be used to develop the emission inventories for the above cities. At the present time, the accuracy and comprehensiveness of any inventory for the U.S. or any specific city will be limited by the available information for the emission sources existing in the U.S. or a city and the control devices in use on the existing sources. The general status of emission inventories for fine particulates is discussed in more detail in the next section.

STATUS OF EMISSION INVENTORIES FOR FINE PARTICULATES

The development of an emission inventory for fine particulates requires a much broader and refined data base than that necessary for an inventory reported on a tonnage basis. The availability and extent of the requisite data imposes definite constraints on the accruacy and precision of emission inventories which can be performed at the present time. Comments on fine particle emission inventories on nationwide, regional or state, and metropolitan bases and a general overview of the subject are presented in the next sections.

NATIONWIDE EMISSION INVENTORIES OF FINE PARTICULATES

Inadequacies in nearly all phases of the data base have severely restricted the accuracy as well as the comprehensiveness of the nationwide emission inventories of fine particulates that MRI has developed to date. Examination of Tables 28 and 29 (pages 69 to 75) in the section that outlines the methodology for using NEDS in future emission inventories shows that the most significant inadequacies are in the areas of particle size distributions of particles emitted from uncontrolled and controlled sources and fractional efficiency curves for various types of control devices. Major extrapolations have been necessitated by the lack of an adequate data base on particle size distributions and control equipment fractional efficiency.

It is also not possible to develop a complete inventory of fine particle emissions for most industry categories because of the lack of emission factor and extent of control information, as well as particle size data, for many processes or operations in a given industry. At the present time, only the most significant sources of particulate pollutants in a given industry (e.g., rotary kilns in cement plants) have been studied in sufficient detail to generate even a partially acceptable data base. Also, fine particle emissions from segments of many industrial categories such as primary nonferrous metallurgy, secondary nonferrous metallurgy, clay products, mineral products, and chemical process industries cannot be estimated because of incomplete data on emission factors, extent of control, particle size, and fractional efficiency of control equipment.

In view of the limitations of the data base, the nationwide emission inventory for fine particles presented in this report should not be considered as more than a "first-cut" or preliminary estimate. In our opinion, the emission figures present a conservative estimate of fine particle emission levels, and the actual emission levels are probably higher than shown in this report.

REGIONAL, STATE OR METROPOLITAN EMISSION INVENTORIES OF FINE PARTICULATES

An inventory of fine particle emissions for a geographical region, state or metropolitan area requires information of the same type as that required for a nationwide inventory except that the information must be available for the specific sources in the given region, state or metropolitan area. The advent of EPA's National Emission Data System (NEDS) has made it possible to consider conducting an inventory of fine particle emissions on a variety of geographical bases. The National Emissions Data System includes: (a) listing of emission sources by city, county, and state; (b) production capacity for each source; (c) type of control equipment on each source; and (d) measured or estimated mass efficiencies of the control systems on each source. By making some modifications to the NEDS retrieval program and expanding the NEDS data bank to include particle size distributions and fractional efficiency data for control equipment, emission inventories for fine particles can be developed for a wide variety of geographical configurations.

The accuracy and comprehensiveness of the inventories will be limited by the degree of completeness of the data base for the geographical regions of interest. A preliminary review of the NEDS information suggests that the major limiting factors will be the availability of reliable particle size and fractional efficiency data.

OVERVIEW OF EMISSION INVENTORIES OF FINE PARTICULATES

Currently, our knowledge of the characteristics of emission sources and control equipment is such that only general indications of the levels of fine particulate emissions from various sources can be provided. The data base required to develop detailed emission inventories is not available at this time. In performing the current and previous emission inventories, MRI has acquired and analyzed all the readily available data on: (a) particle size distributions of particles from uncontrolled and controlled sources; (b) fractional efficiency curves for specific control devices; (c) the degree of application of control equipment for specific sources; and (d) mass emission factors. Deficiencies exist in the data in each of the above categories, and the deficiencies range from minor to very significant. In order to refine the emission inventories it will be necessary to upgrade every aspect of the data base. Our recommendations for additional research are presented in the next section of this report.

RECOMMENDATIONS FOR FUTURE WORK

In view of the increasing interest in the fine particulate pollution problem, MRI believes that a program to upgrade the data base needed to perform emission inventories for fine particulates and to assess the importance of man-made contributions should be initiated. Output from the recommended programs will result in a clearer definition of the pollution problem from fine particulates.

In order to refine existing emission inventories for fine particles, it will be necessary to upgrade the data base with respect to each factor in Eqs. (1) and (2), pages 20 and 21. However, available information on production or consumption rates and emission factors is in general more reliable than is the available information on percentage of production capacity on which control equipment is installed, particle size distribution of emitted particles, and fractional efficiency of control equipment. Priority in future programs should be given to refining the data base for the latter three factors. In addition, because it is currently necessary to make major extrapolations of available data on particle size distributions and fractional efficiency, special emphasis should be placed on acquiring new and more reliable data for these two important terms.

Field testing on carefully selected control equipment source combinations should be a major part of activities to improve the existing data base. Efforts in the recommended field testing activity should be focused on obtaining additional information relative to:

1. Particle size distributions of particles emitted from uncontrolled and controlled sources, and

2. Fractional efficiency characteristics of control equipment.

Source testing and particle sizing procedures have been improved to the point where the acquisition of reliable data is a reasonable expectation of field testing programs. For example, during the past year, techniques have been utilized which are capable of measuring particle size distributions down to 0.2 μ using inertial impactors, and to about 0.01 μ with diffusion batteries. Mass emission factor data which might well be a by-product of the field testing activity could be incorporated into the existing data base on emission factors.

Concurrent with activities to obtain improved particle size and fractional efficiency data, efforts should be made to refine available information on the use of various types of control equipment on specific sources of particulate pollutants. An updating of EPA's NEDS system, supplemented as needed by additional surveys of control equipment utilization, would be the most efficient approach to obtaining the needed information on equipment utilization.

A significant gap also exists in our knowledge of the operational reliability of installed control systems. In calculating mass or fine particle emissions from controlled sources it is usually assumed that control equipment is in operation 100% of the time that a source is operating. This is seldom the case, but data are generally not available on control equipment operational availability. An indication of the potential error in this type of assumption is provided by the results of a survey reported in Ref. 24. In Ref. 24, Greco and Wynot report the results of a study dealing with the performance and availability of electrostatic precipitators of 16 different design types serving 51 power generating units of TVA. The overall weighted average availability was reported to be 92.6% for a 1-year period of operation.

In most industries the records of control equipment operational reliability have not been reported or are not available. The availability factor assumes considerable importance as emission inventories of fine particulate pollutants become more refined. For example, an electrostatic precipitator of 99.5% overall mass efficiency which operates only 92.6% of the time a source operates is really equivalent to a net efficiency of 92.1%--a reduction of ~7.5% in actual collection efficiency and an increase by a factor of 15 in emissions. It is recommended that studies or surveys be conducted to define the actual operational reliability of control equipment.

Because of the influence of atmospheric conversion processes and particulate removal mechanisms on the fine particulate burden in the atmosphere, it is difficult to relate fine particulate loadings in the atmosphere to specific sources or to emission control programs on various sources. The formation of secondary fine particulates in the atmosphere represents a major problem in assessing man-made and natural contributions to the total atmospheric loading. The state of understanding of the chemical mechanisms and reaction rates involved in secondary particulate formation is not advanced to the point of being included in any transport and transformation models. Additional research is recommended to delineate the mechanisms of secondary particulate formation and transport.

Only limited effort has been devoted to defining the removal mechanisms for fine particulates in the atmosphere. The questions of how particulates get removed and whether these removal rates are dependent on land use, surface foliage, and other factors are suggested as topics for future research programs.

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APPENDIX A

PARTICLE-SIZE DISTRIBUTIONS

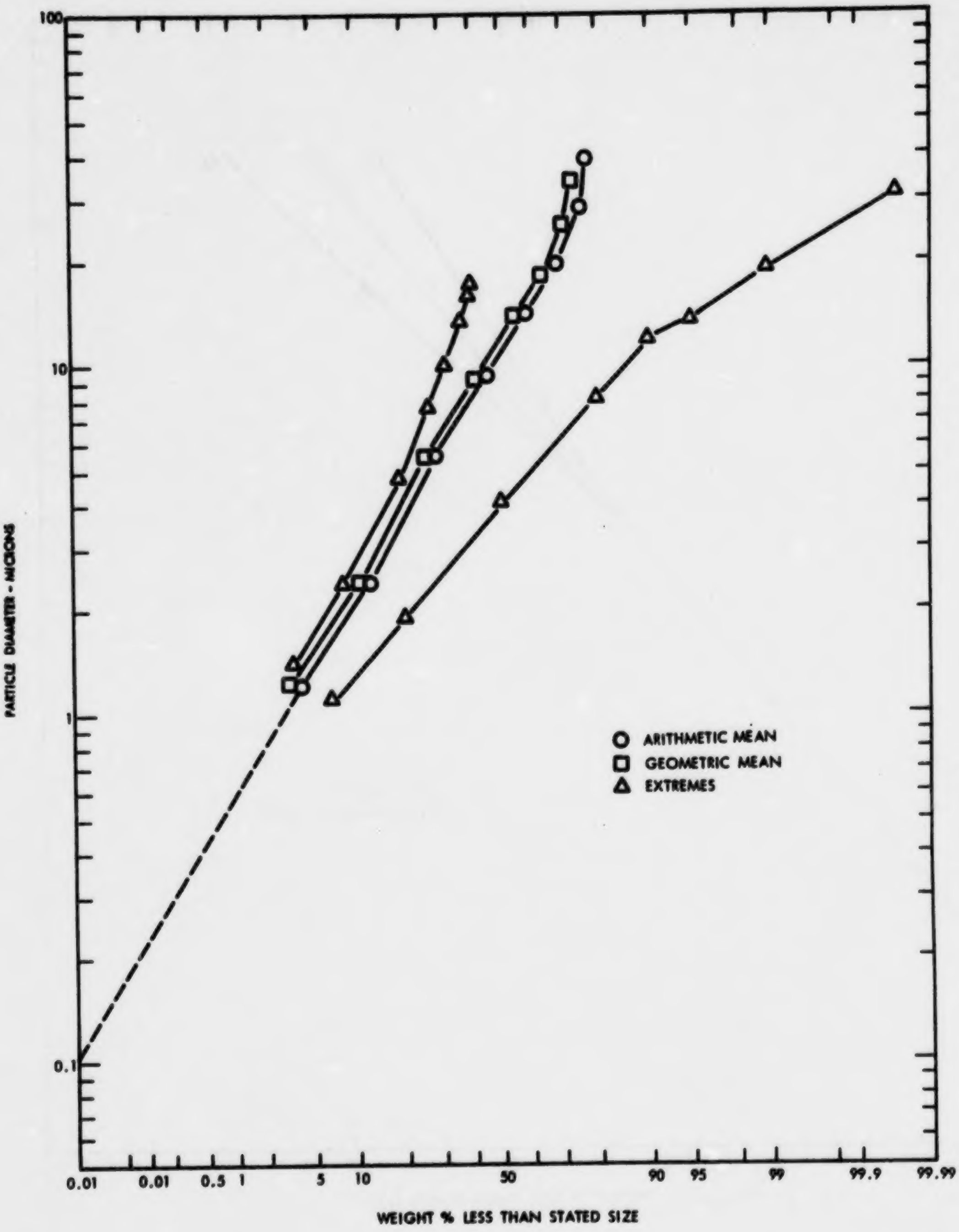

Figure A-1. Particle-size distribution of particulates emitted from uncontrolled hot-mix asphalt plant dryers (Bahco data)

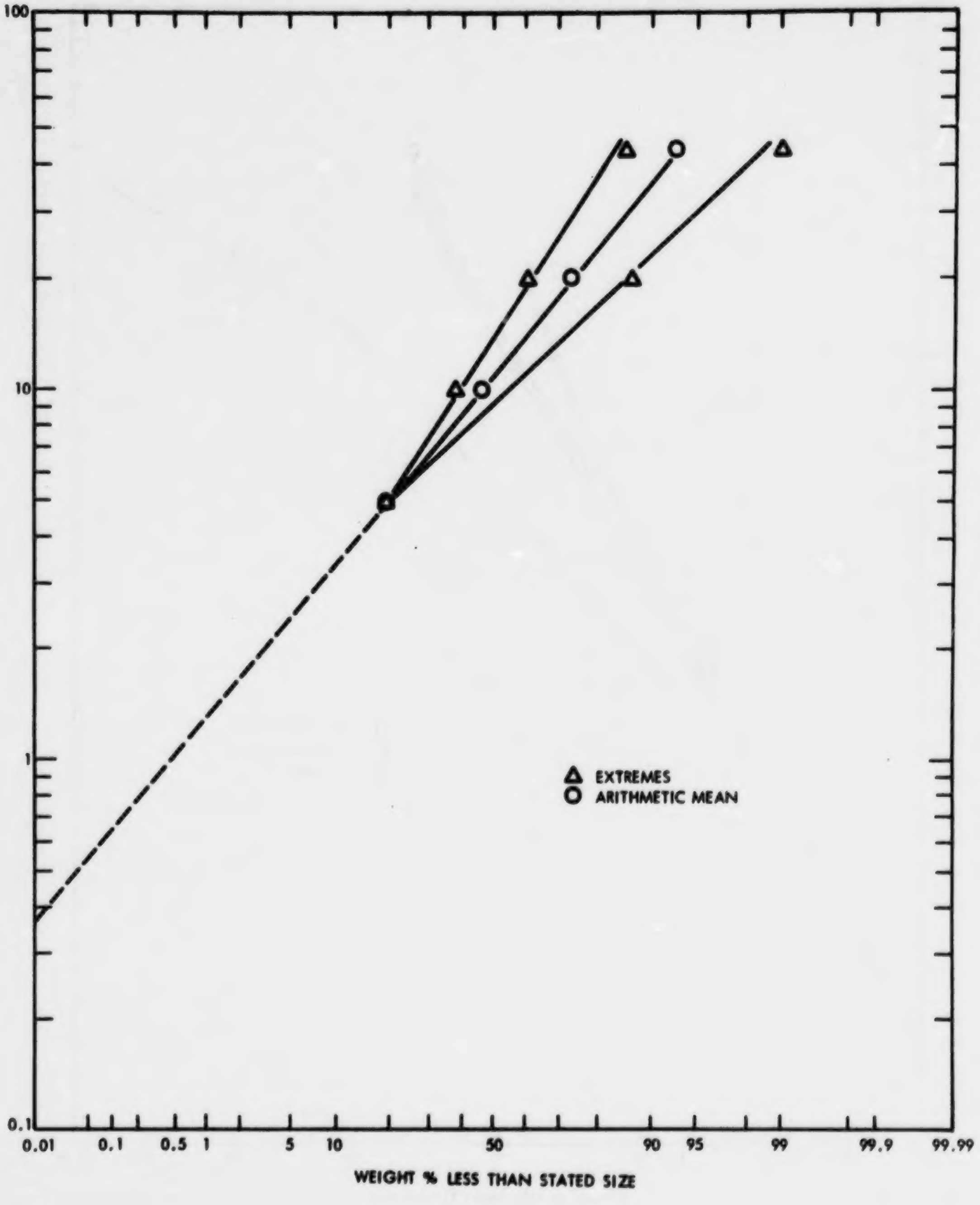

Figure A-2. Particle-size distribution of particulates emitted from uncontrolled hot-mix asphalt plant vent lines (Bahco data)

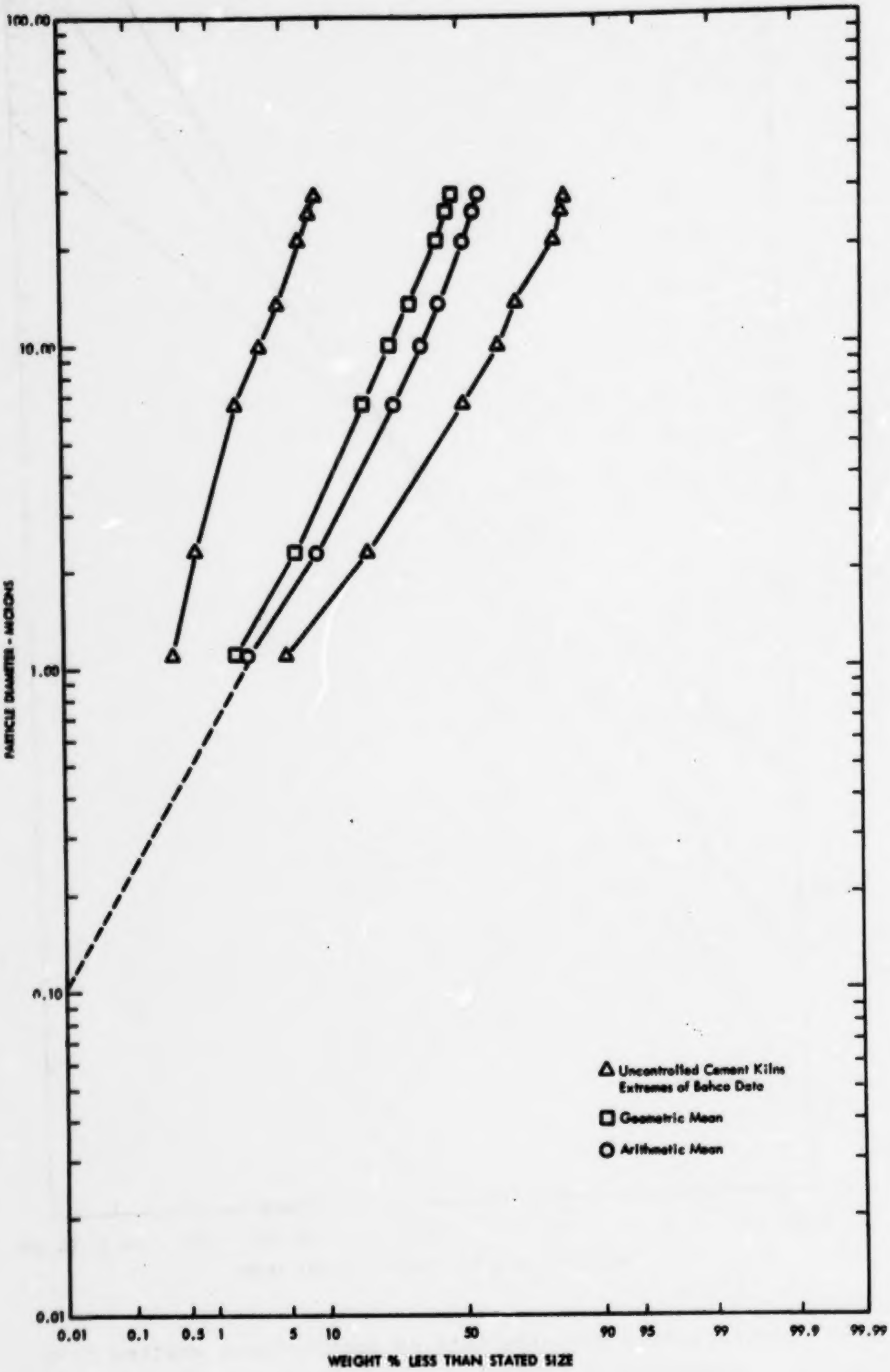

Figure A-3. Particle-size distributions of particulates emitted from uncontrolled cement kilns

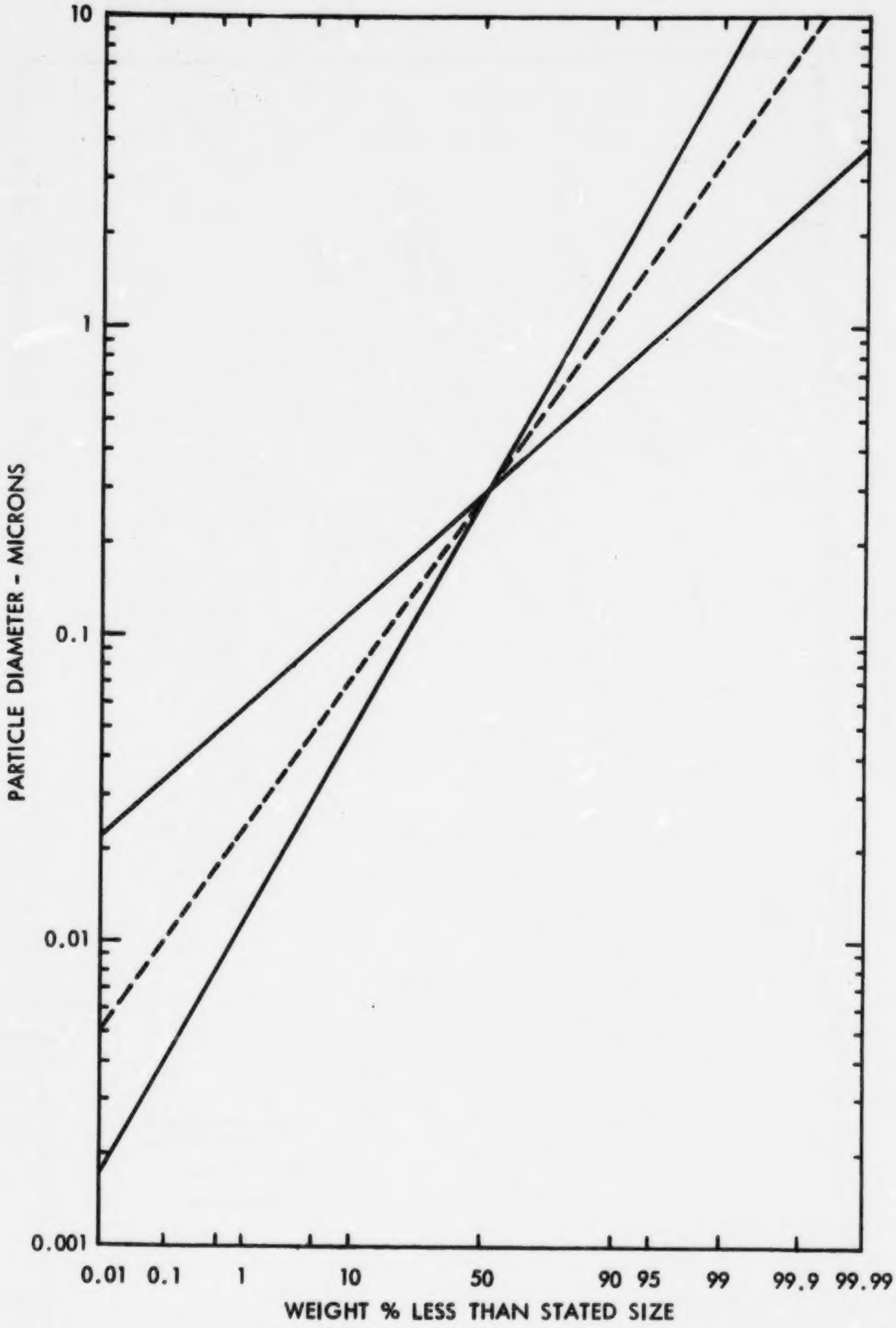

Figure A-4. Particle-size distributions of particulates emitted from uncontrolled ferroalloy electric furnaces producing ferrosilicon alloys

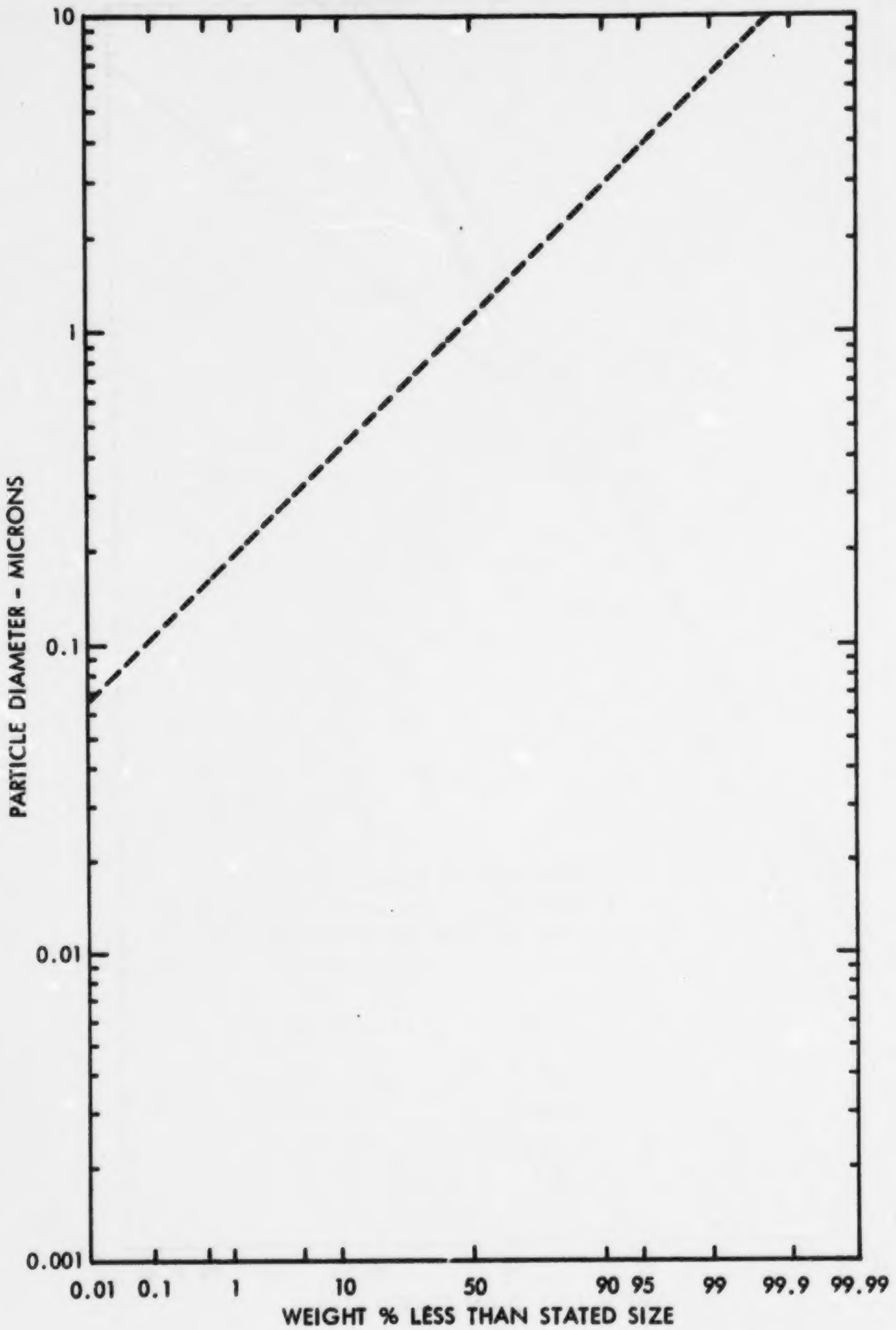

Figure A-5. Particle-size distribution of particulates emitted from uncontrolled ferroalloy electric furnaces producing ferromanganese alloys

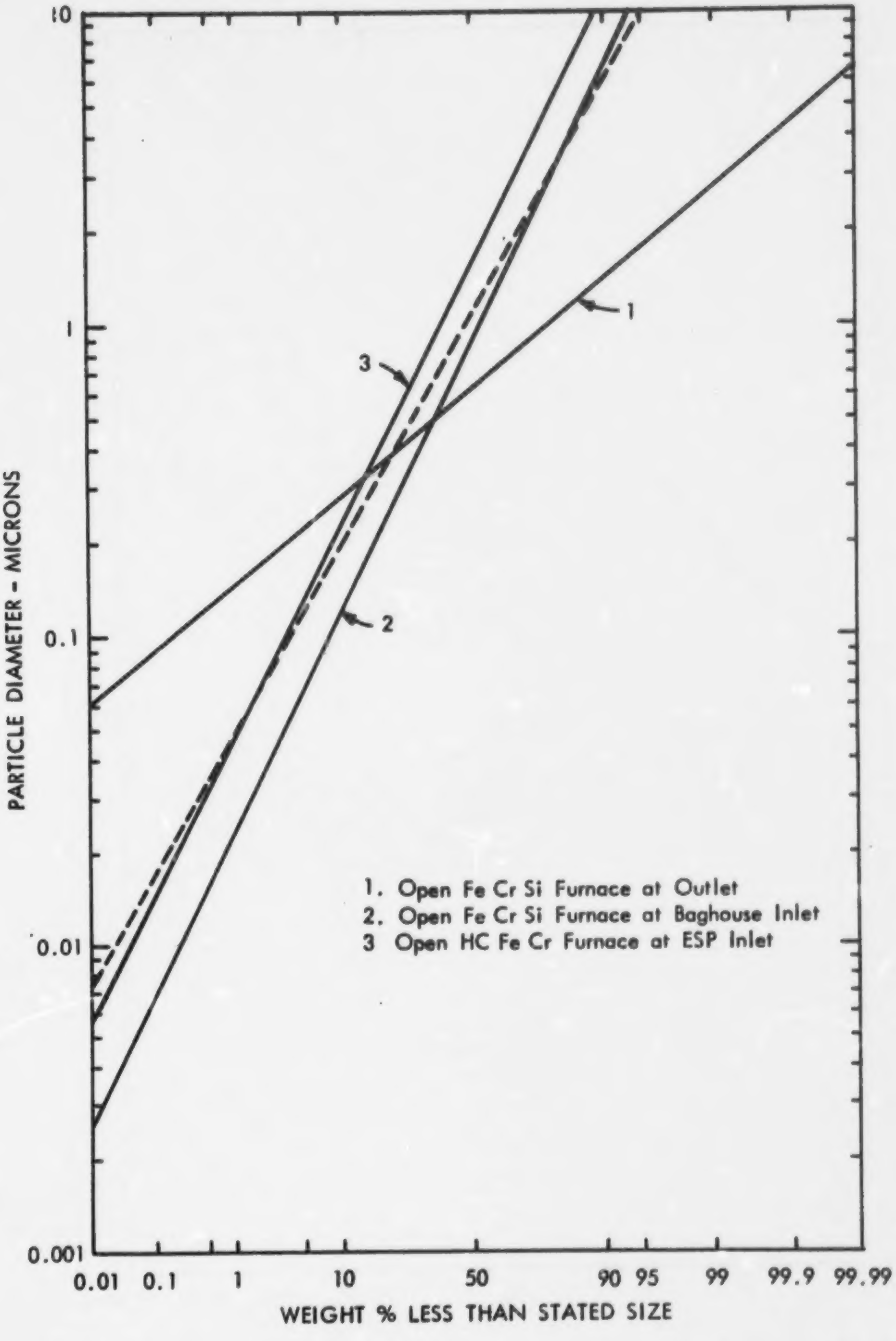

Figure A-6. Particle-size distribution of particulates emitted from uncontrolled ferroalloy electric furnaces producing ferrochromium alloys

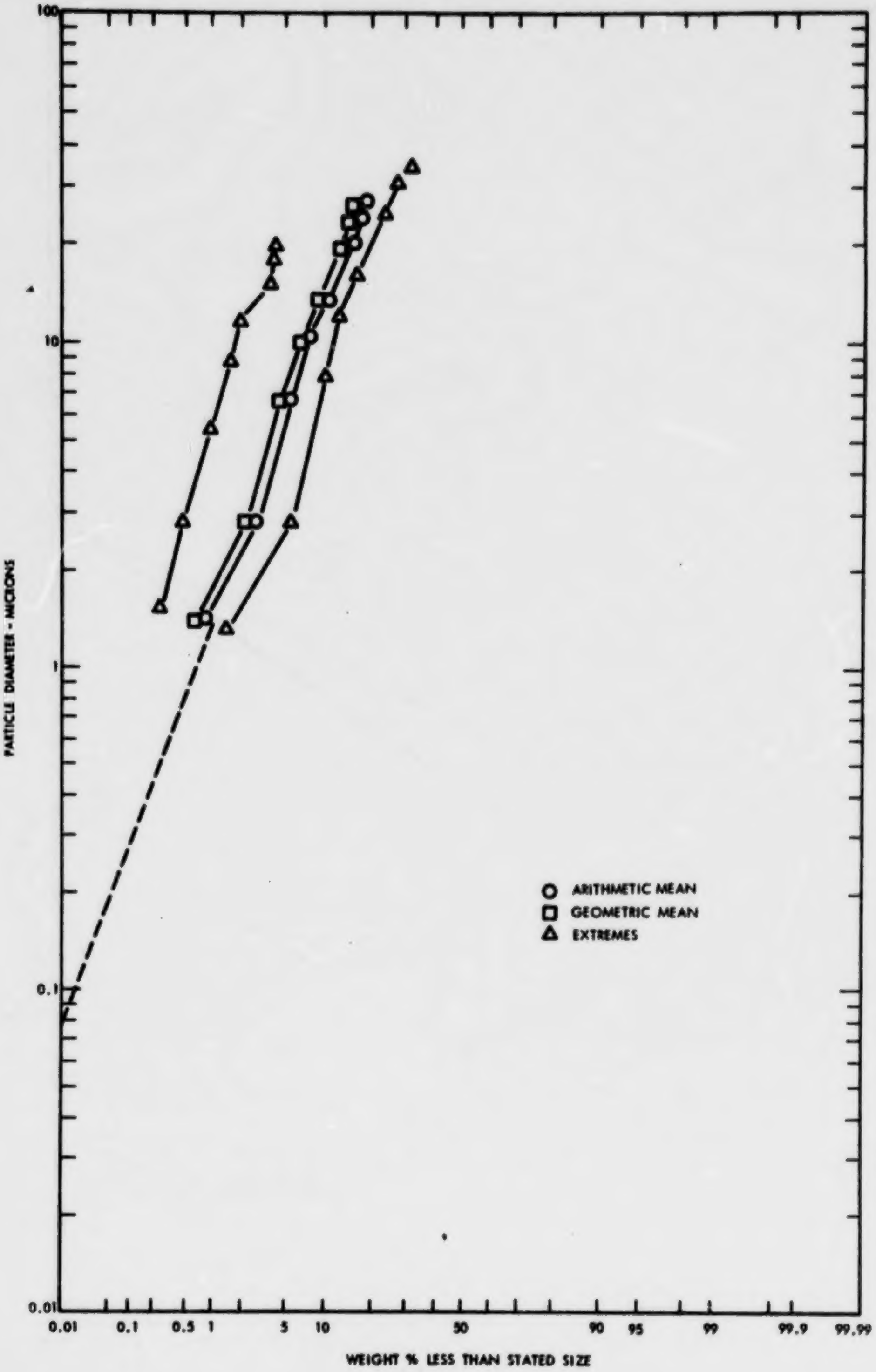

Figure A-7. Particle-size distribution of particulates emitted from uncontrolled fertilizer dryers (Bahco data)

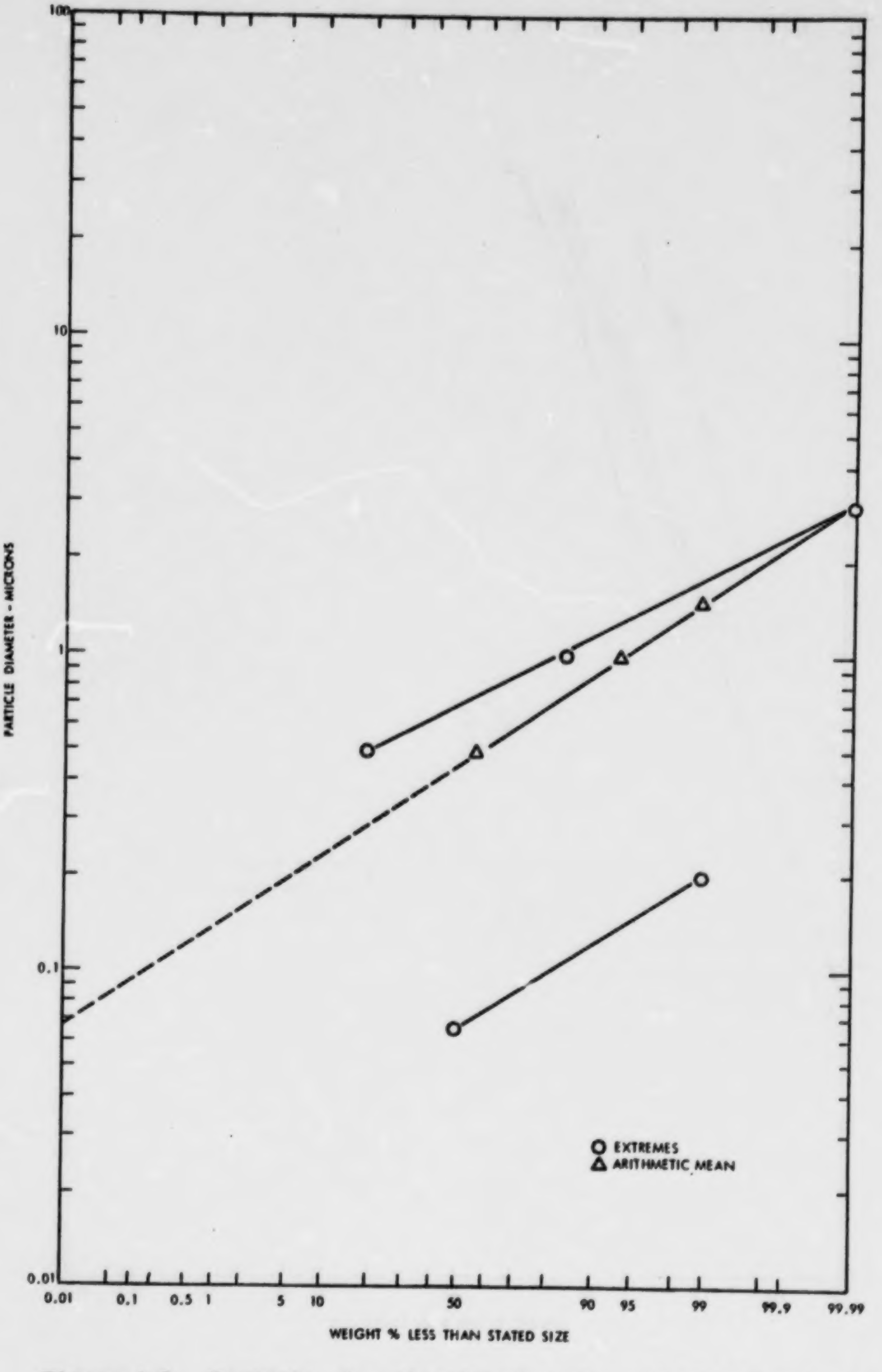

Figure A-8. Particle-size distribution of particulates emitted from uncontrolled basic oxygen furnaces

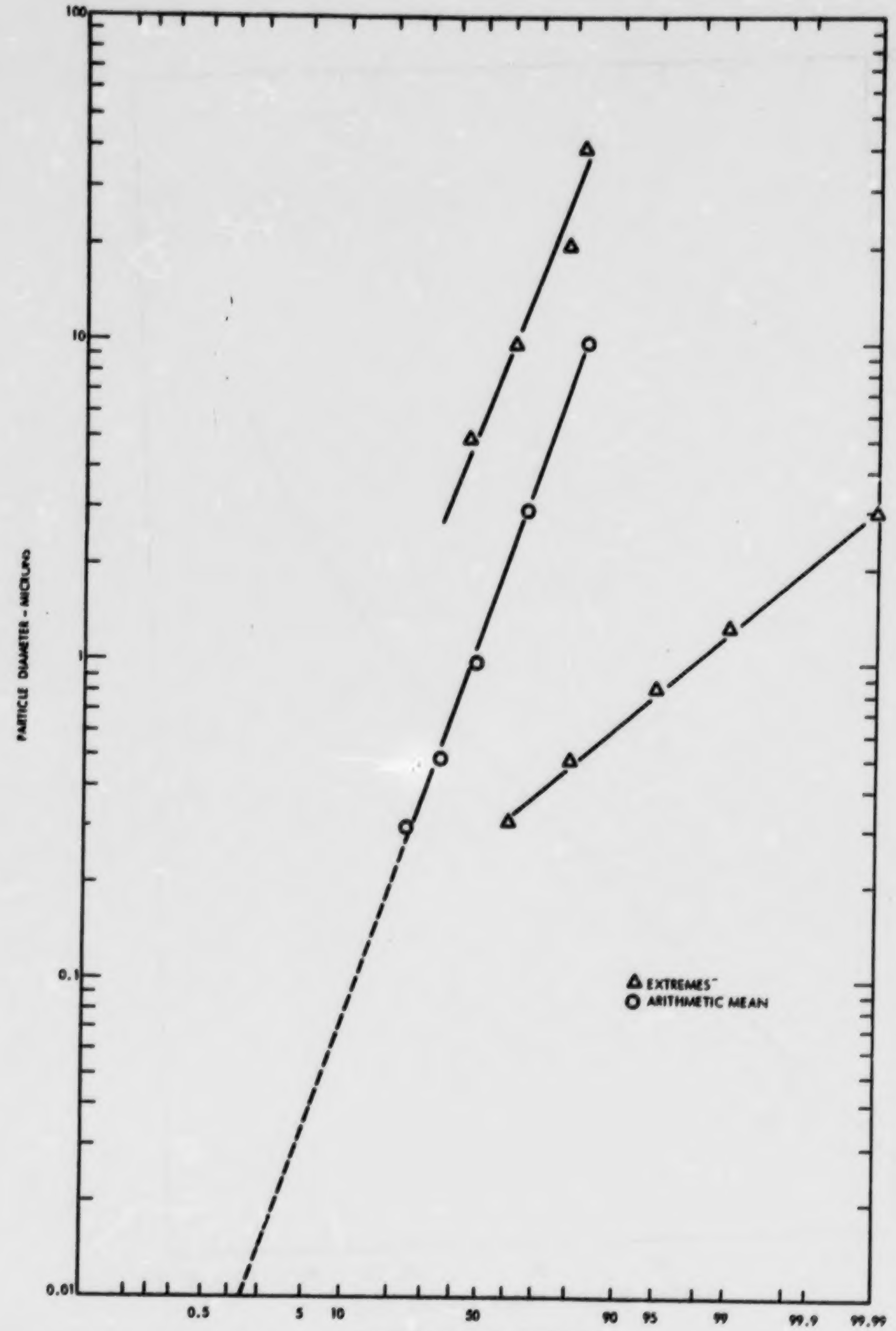

Figure A-9. Particle-size distribution of particulates emitted from uncontrolled electric arc furnaces

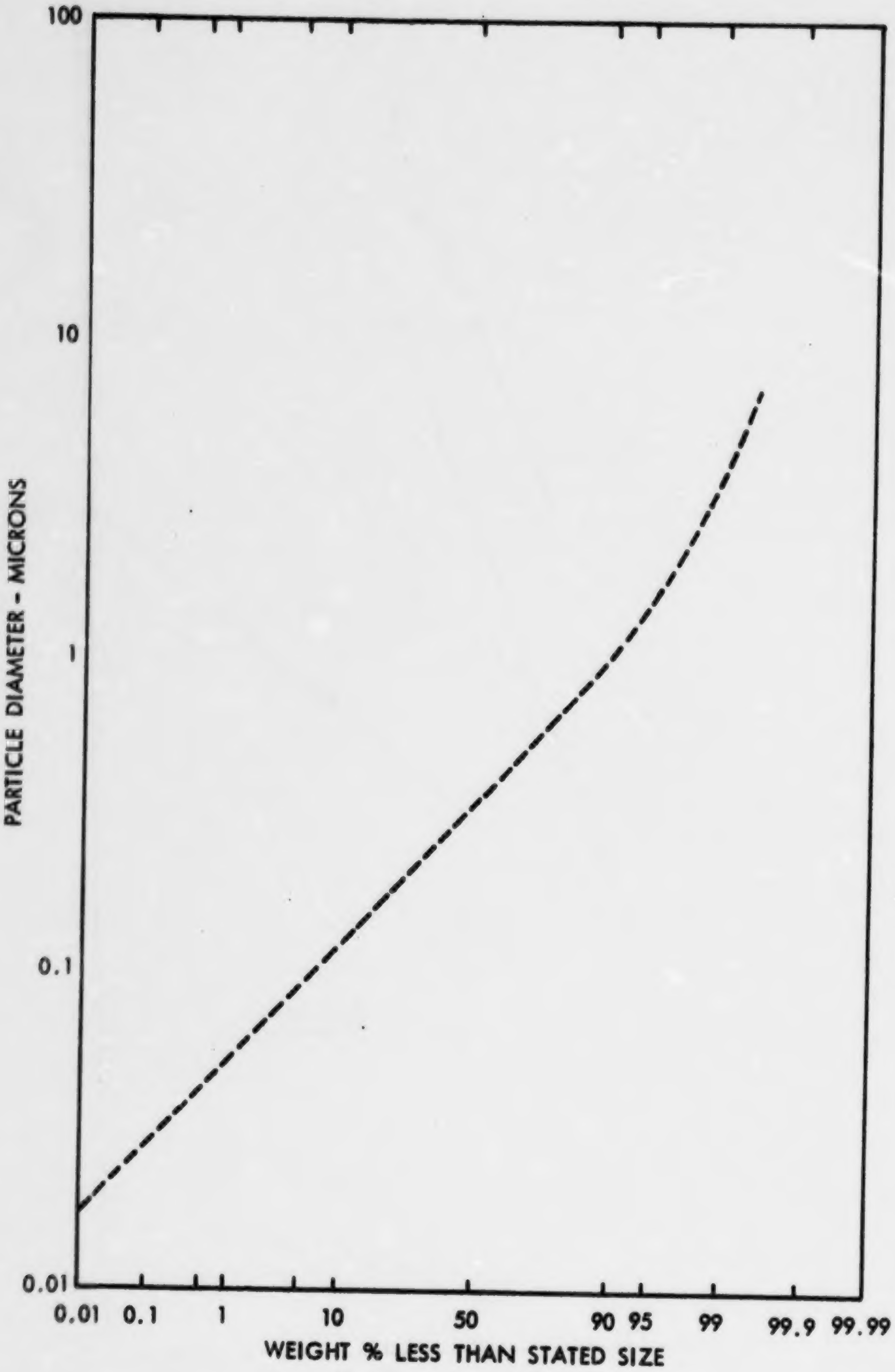

Figure A-10. Particle-size distribution of particulates emitted from uncontrolled iron and steel plant open hearth furnaces

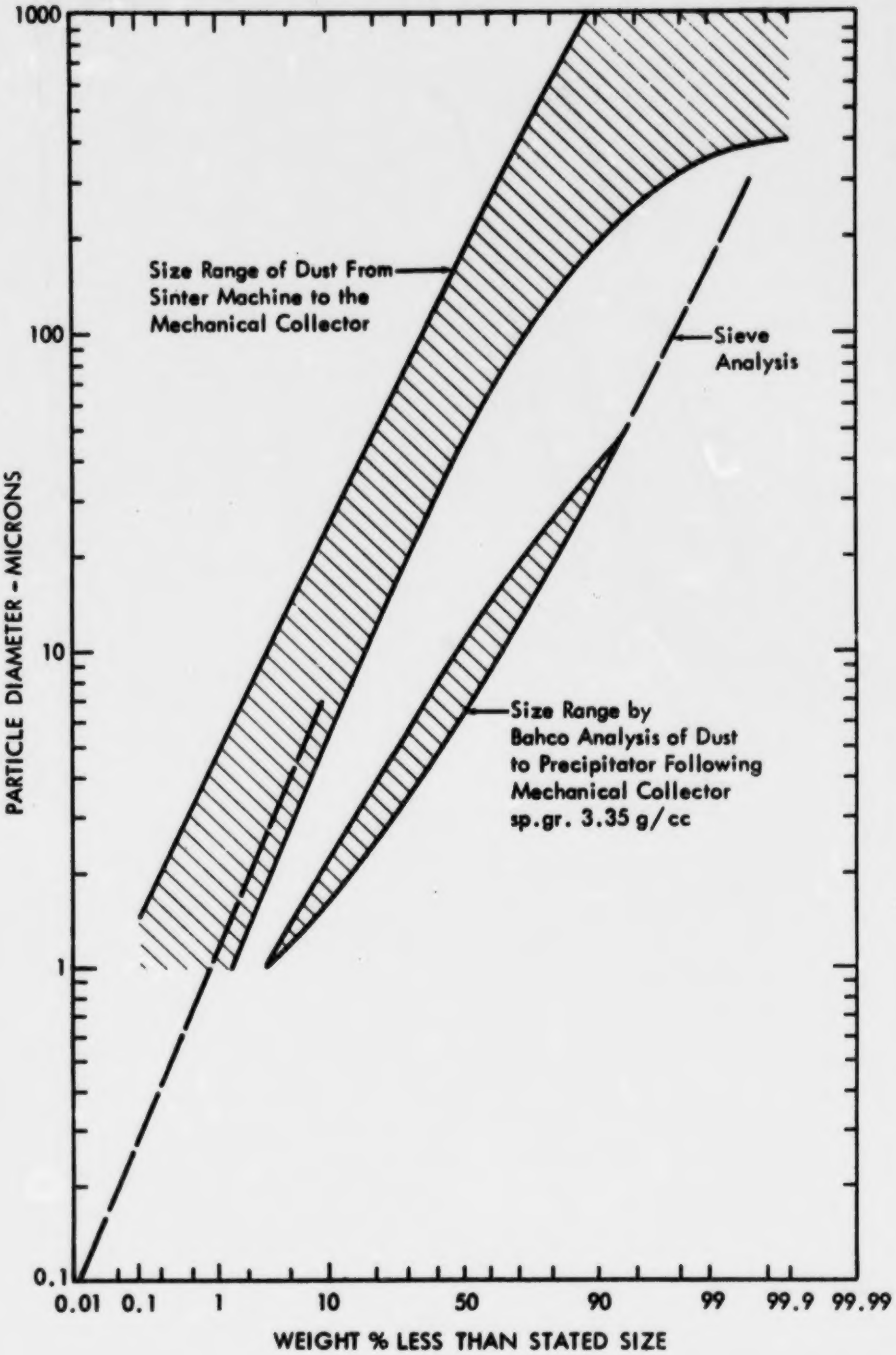

Figure A-11. Particle-size distribution of particulates emitted from uncontrolled iron and steel plant sintering machine windbox

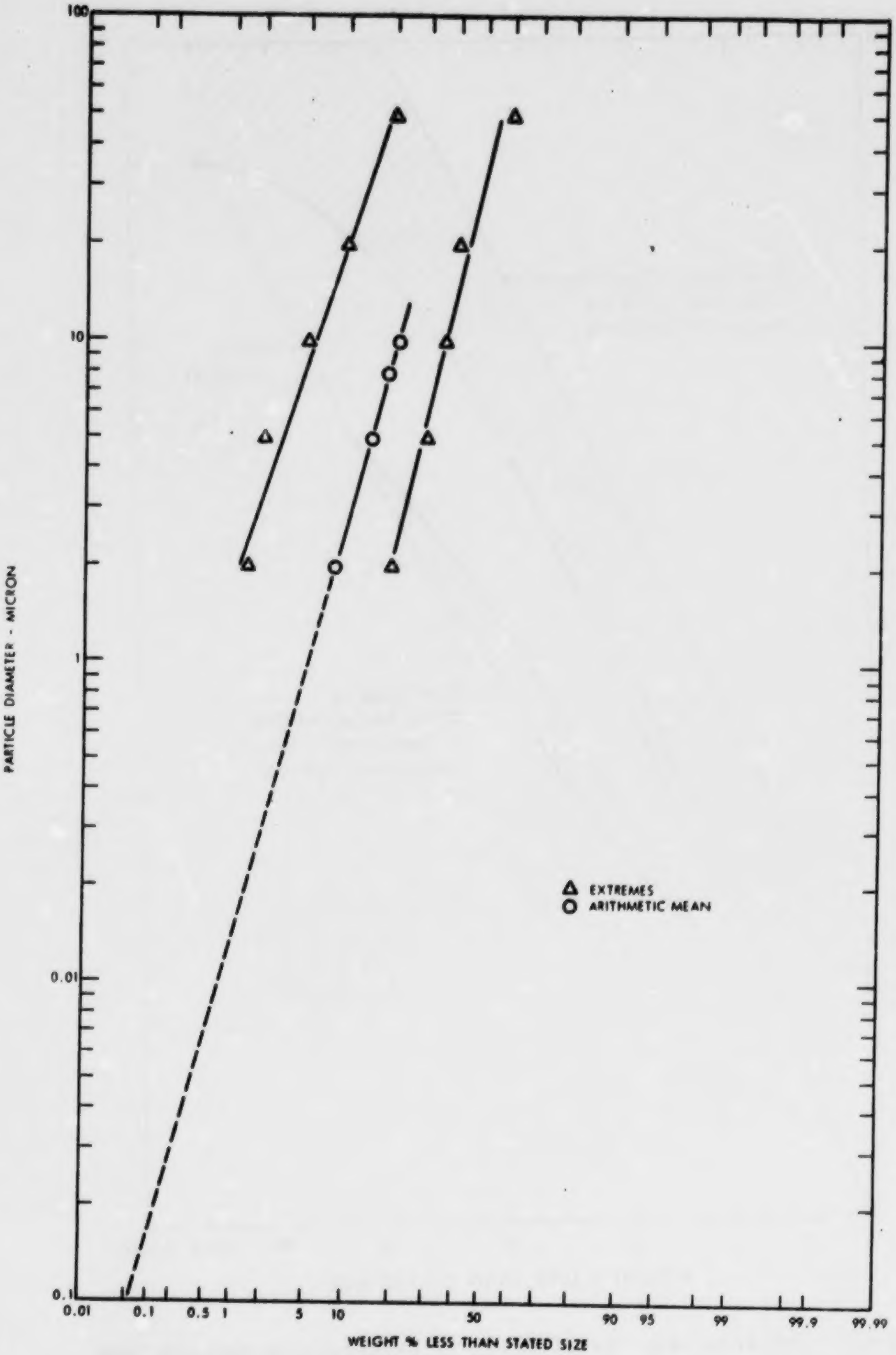

Figure A-12. Particle-size distribution of particulates emitted from uncontrolled iron foundry cupolas (Bahco data)

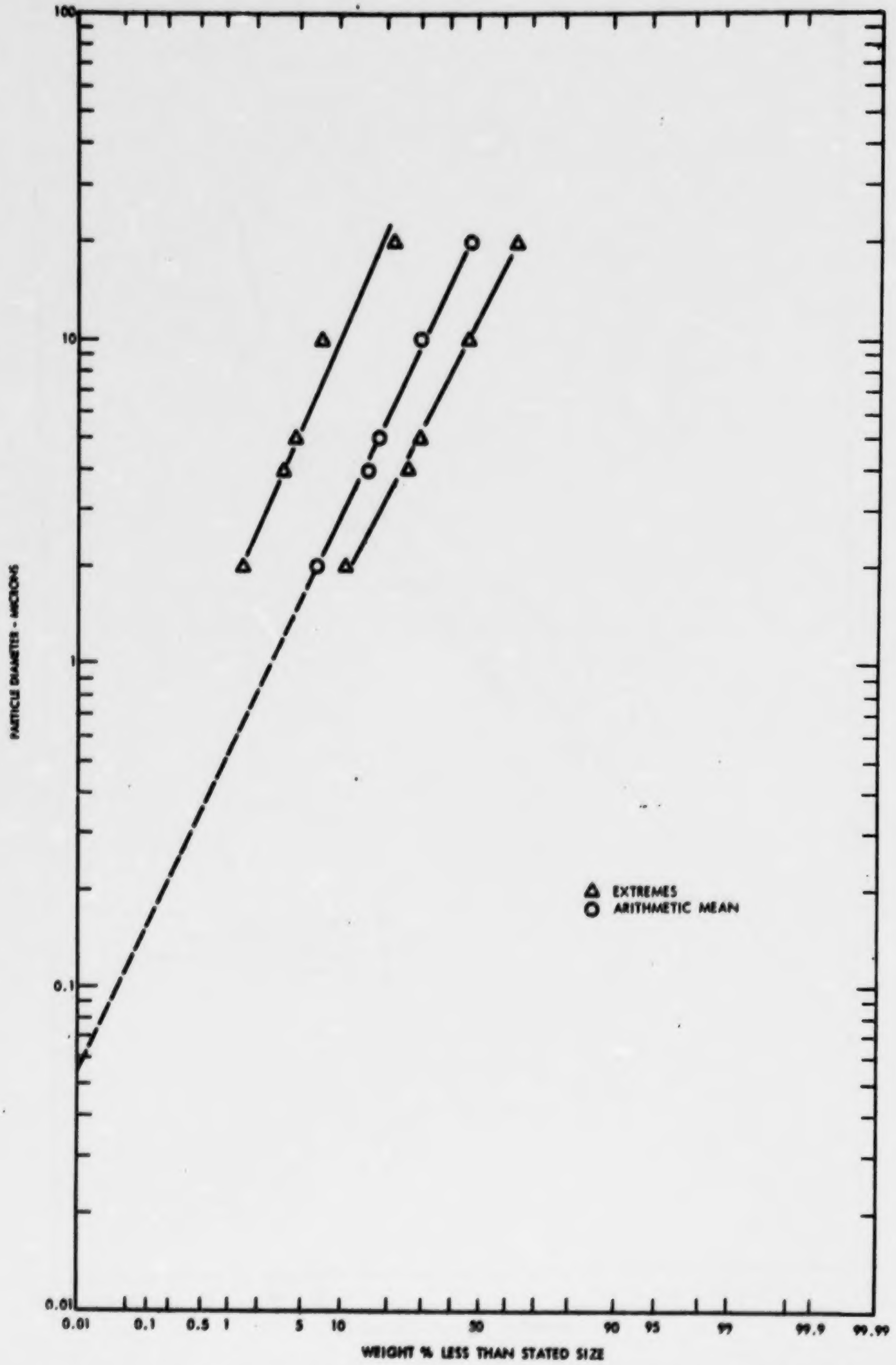

Figure A-13. Particle-size distribution for particulates emitted from uncontrolled pulp mill bark boilers (Bahco data)

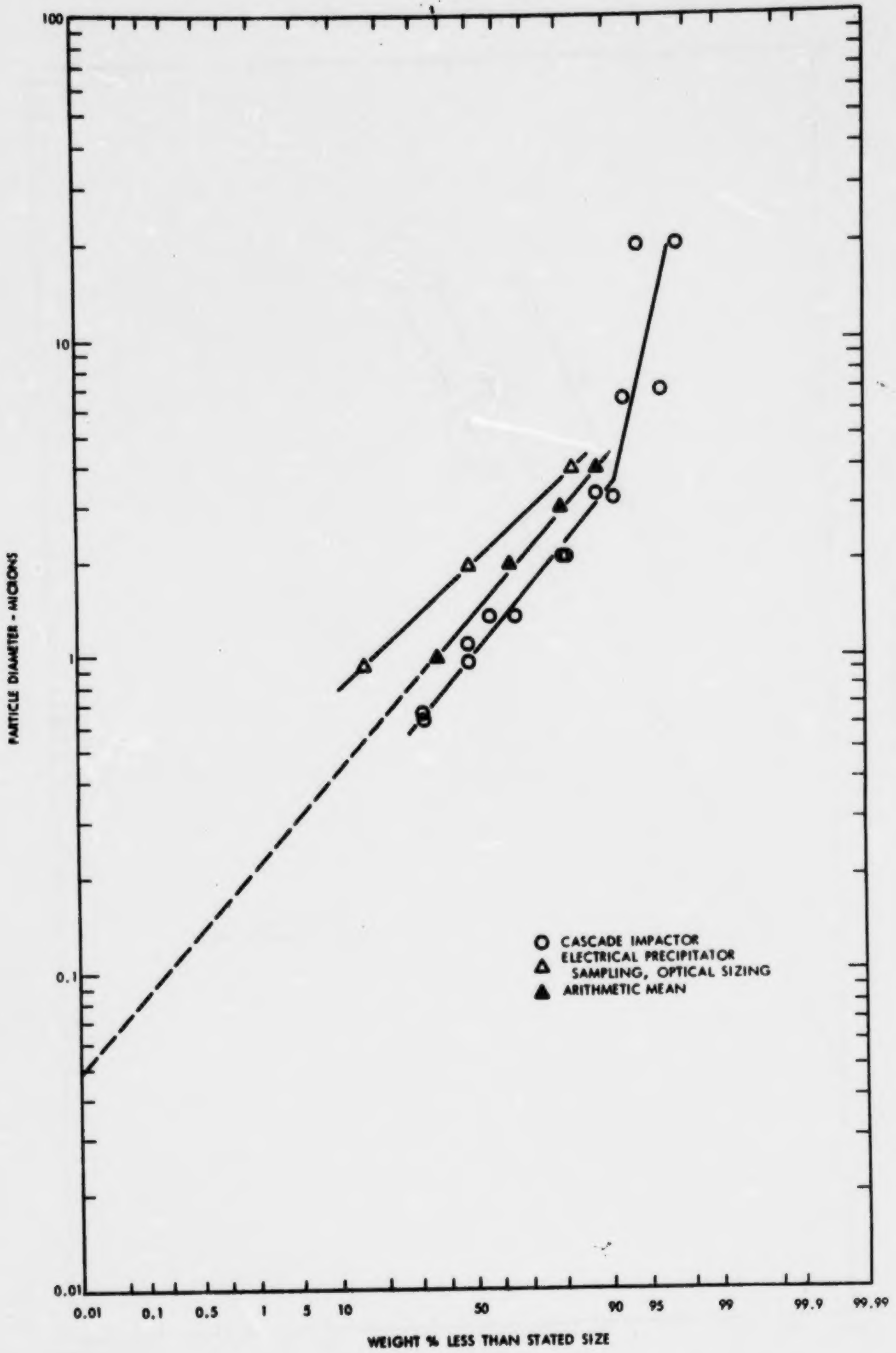

Figure A-14. Particle-size distribution for particulates emitted from uncontrolled pulp mill recovery furnaces

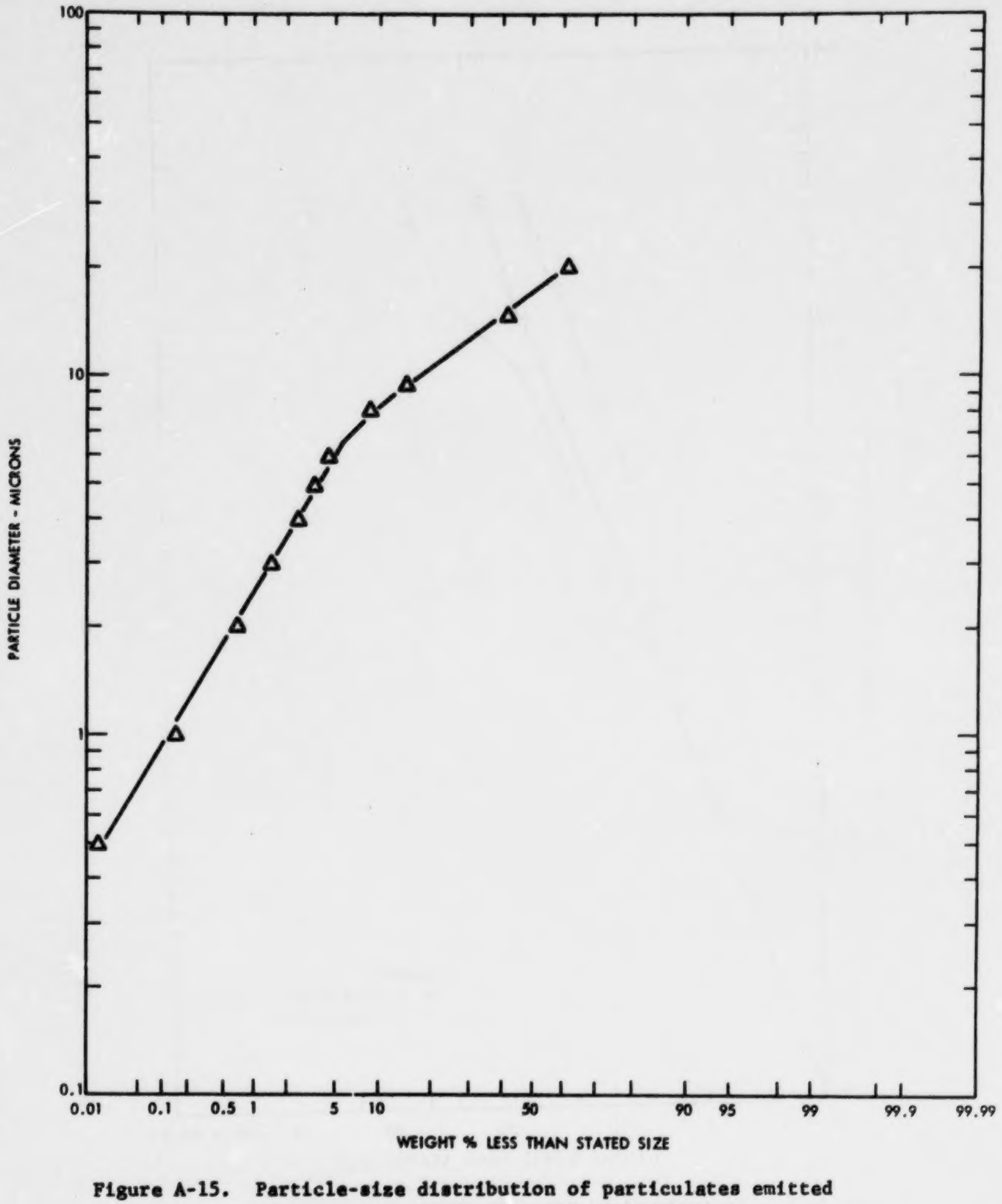

Figure A-15. Particle-size distribution of particulates emitted from uncontrolled pulp mill lime kilns

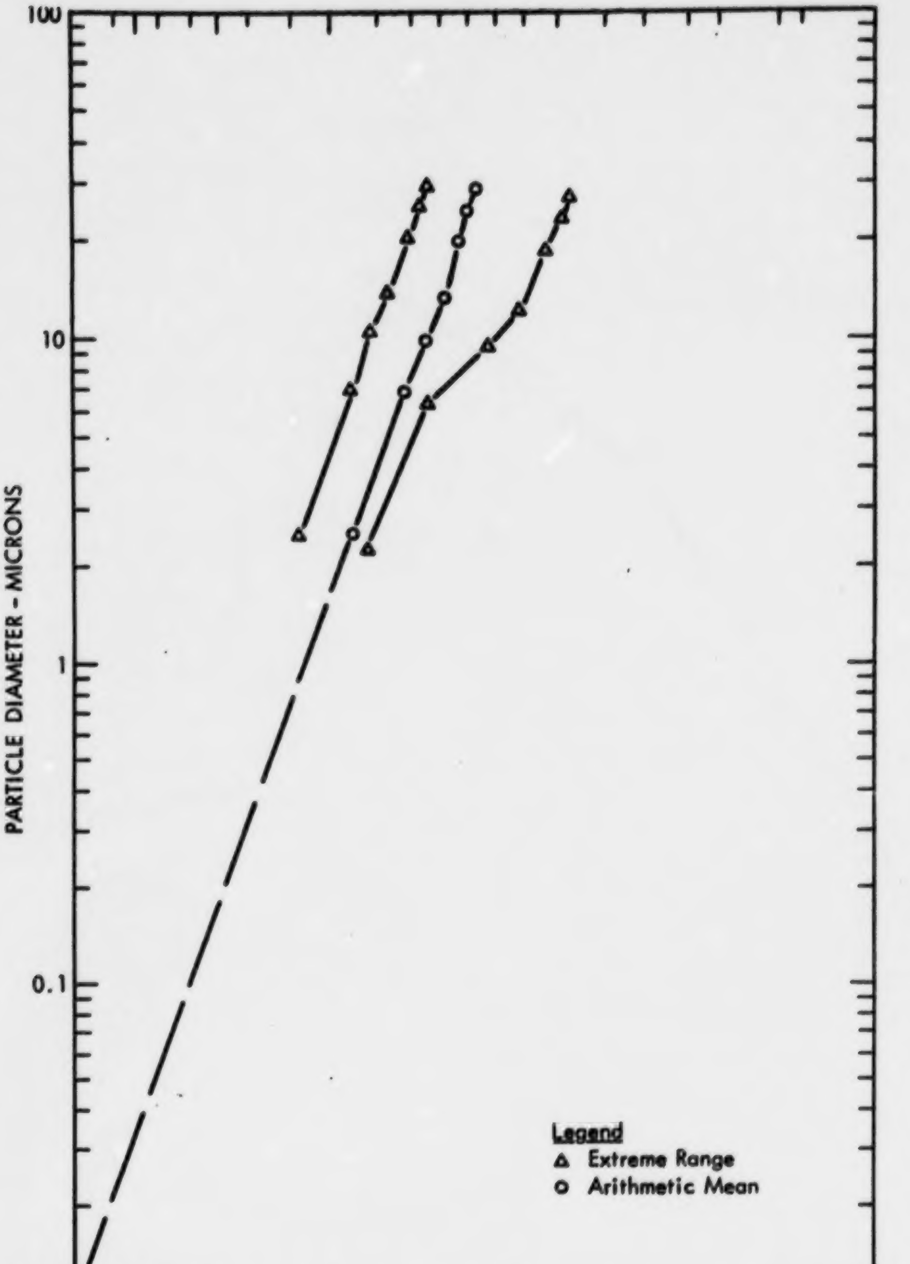

Figure A-16. Particle-size distribution of particulates emitted from uncontrolled lime plant rotary kilns

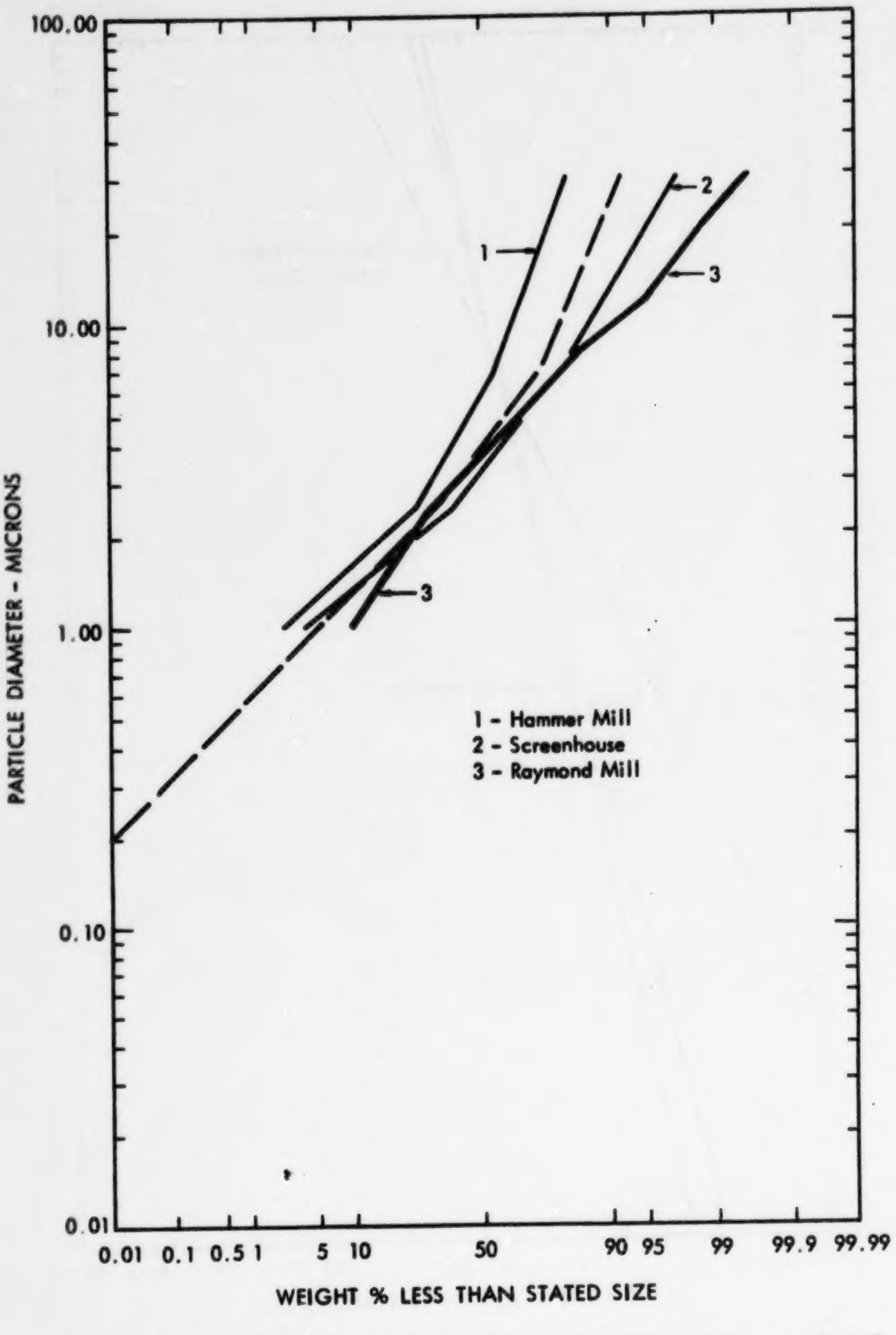

Figure A-17. Particle-size distribution of particulates emitted from uncontrolled lime plant secondary sources

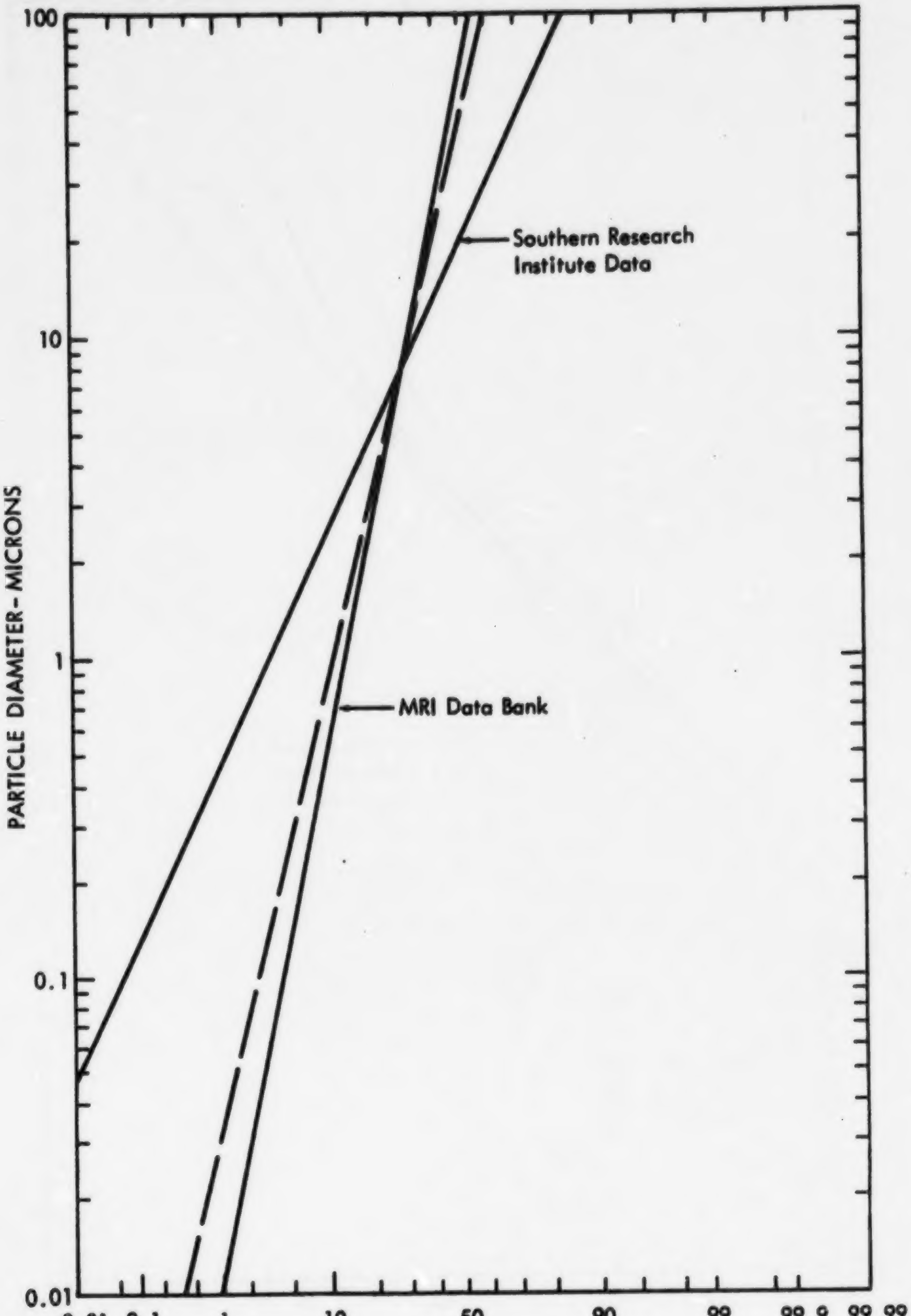

Figure A-18. Particle-size distribution of particulates emitted from uncontrolled municipal incinerators

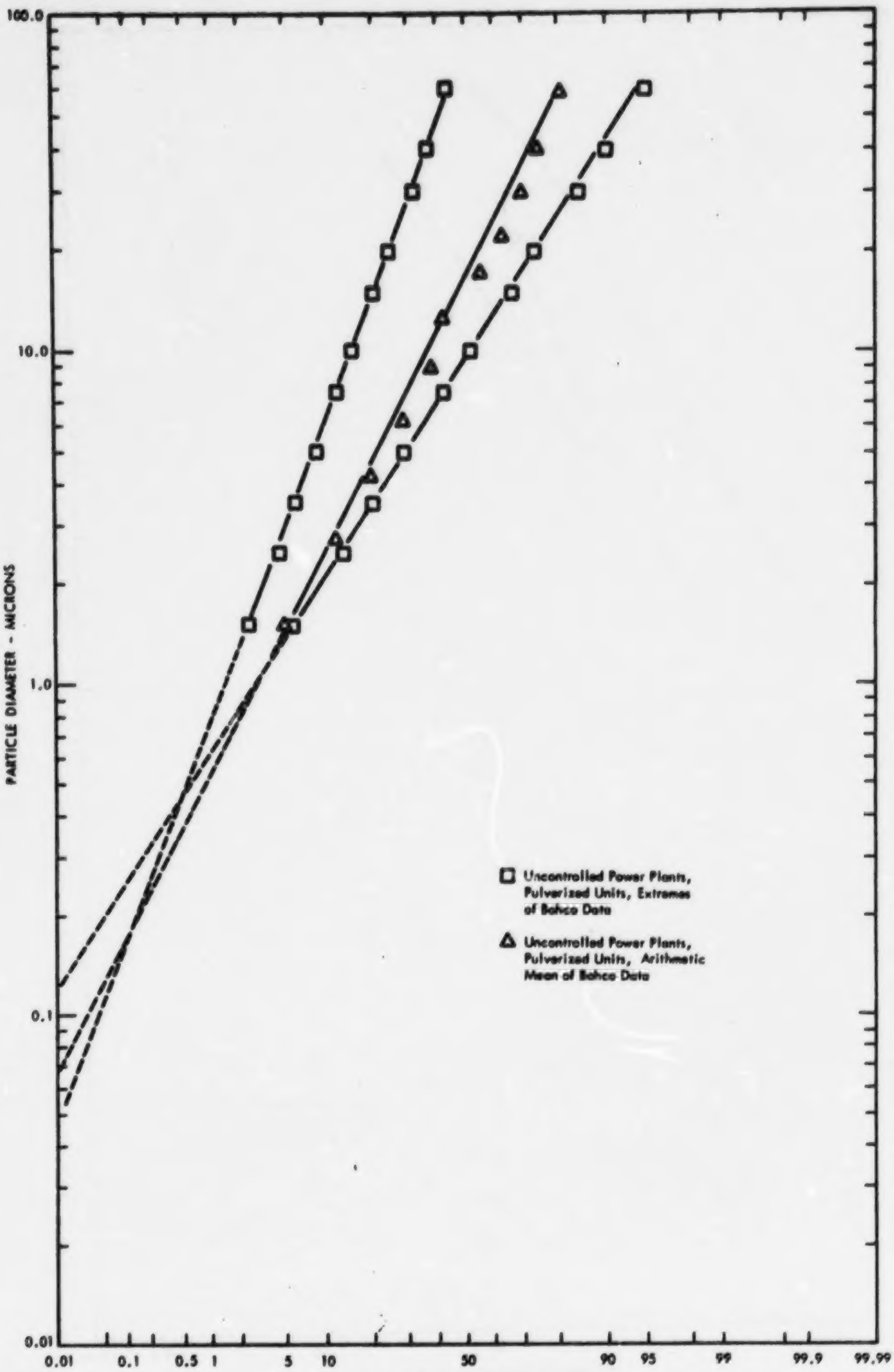

Figure A-19. Particle-size distributions of particulates emitted from uncontrolled power plants (pulverized coal-fired boilers)

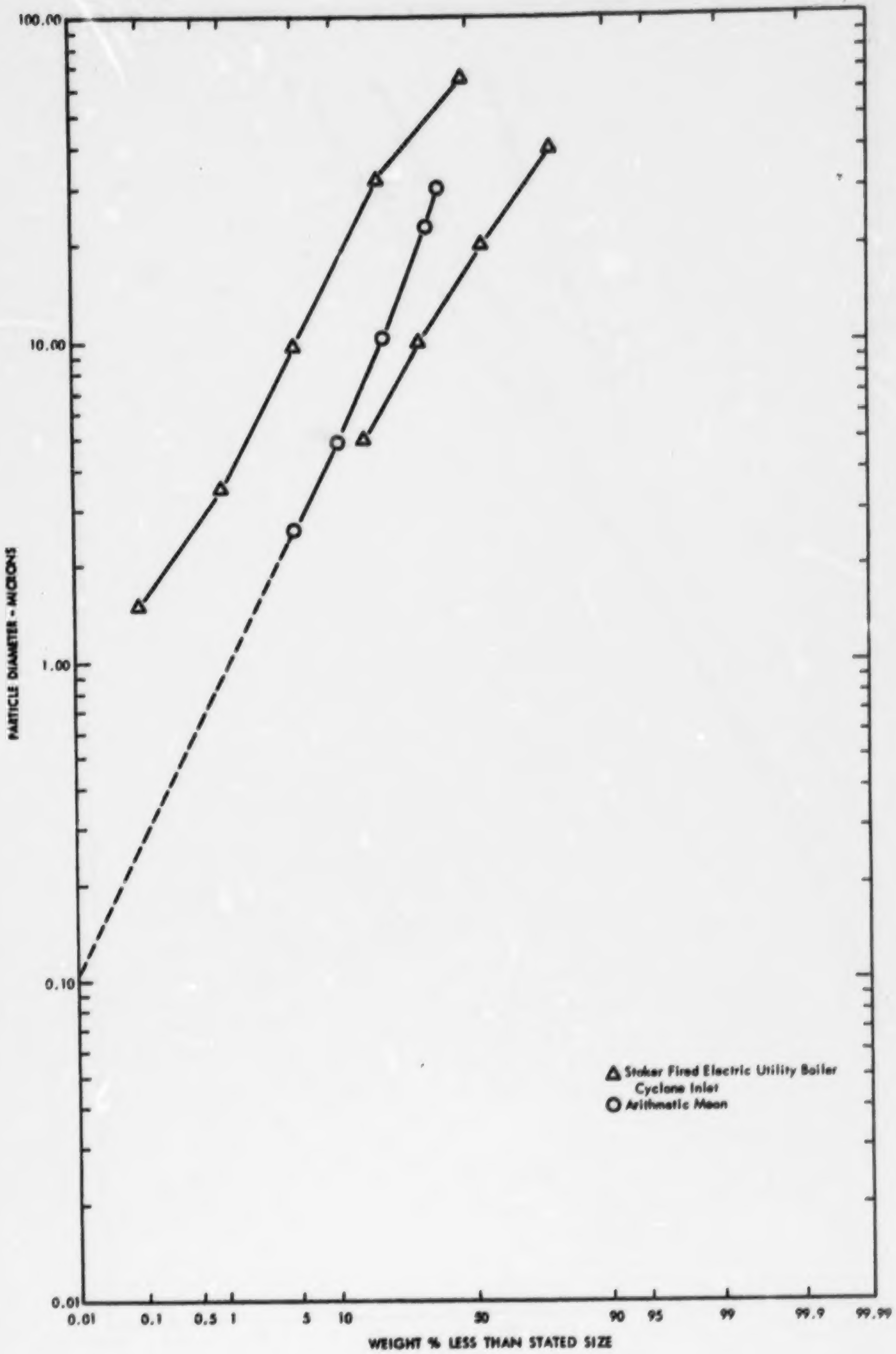

Figure A-20. Particle-size distribution of particulates emitted from uncontrolled power plants (stoker coal-fired boilers)

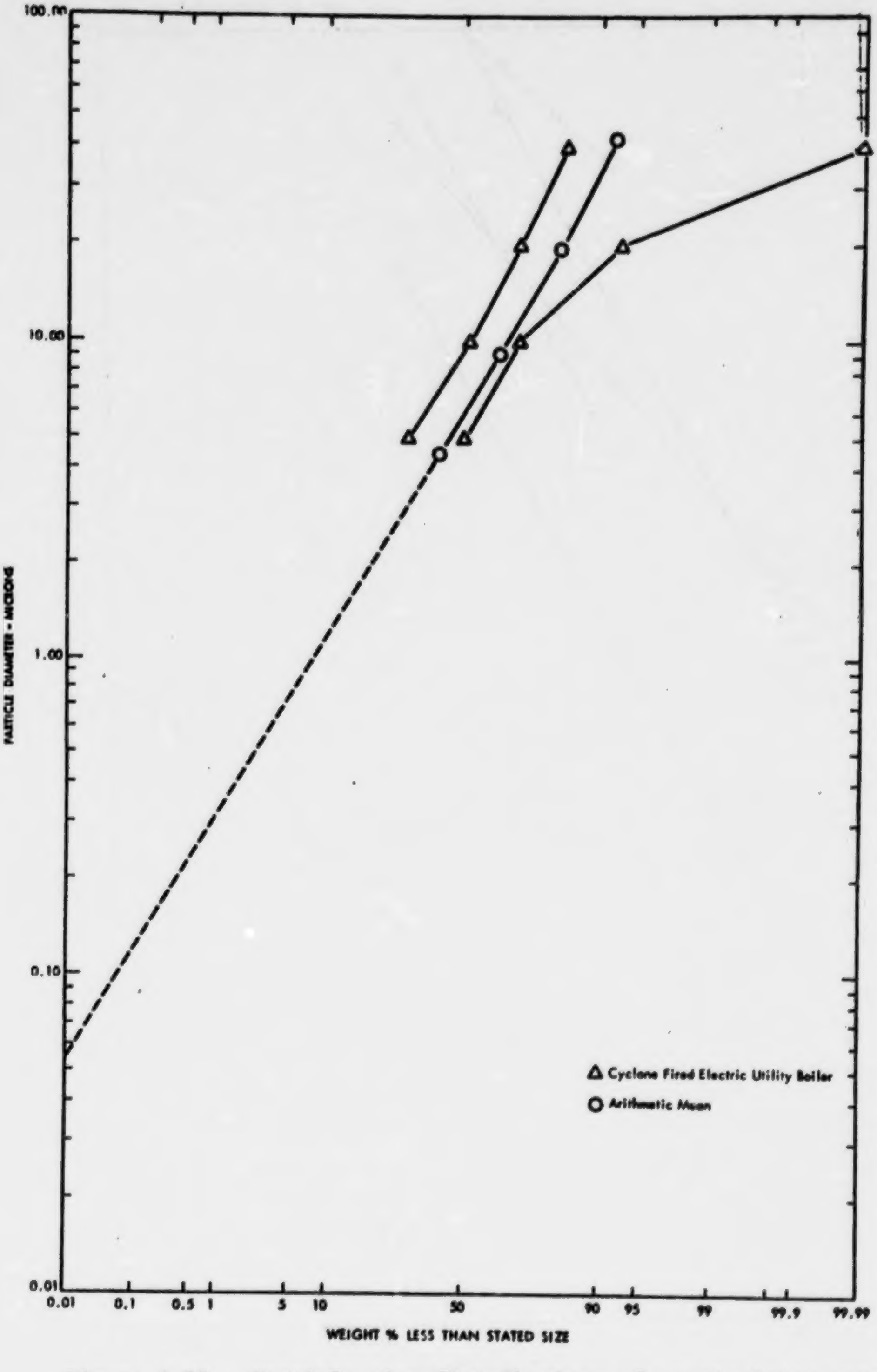

Figure A-21. Particle-size distributions of particulates emitted from uncontrolled power plants (cyclone coal-fired boilers)

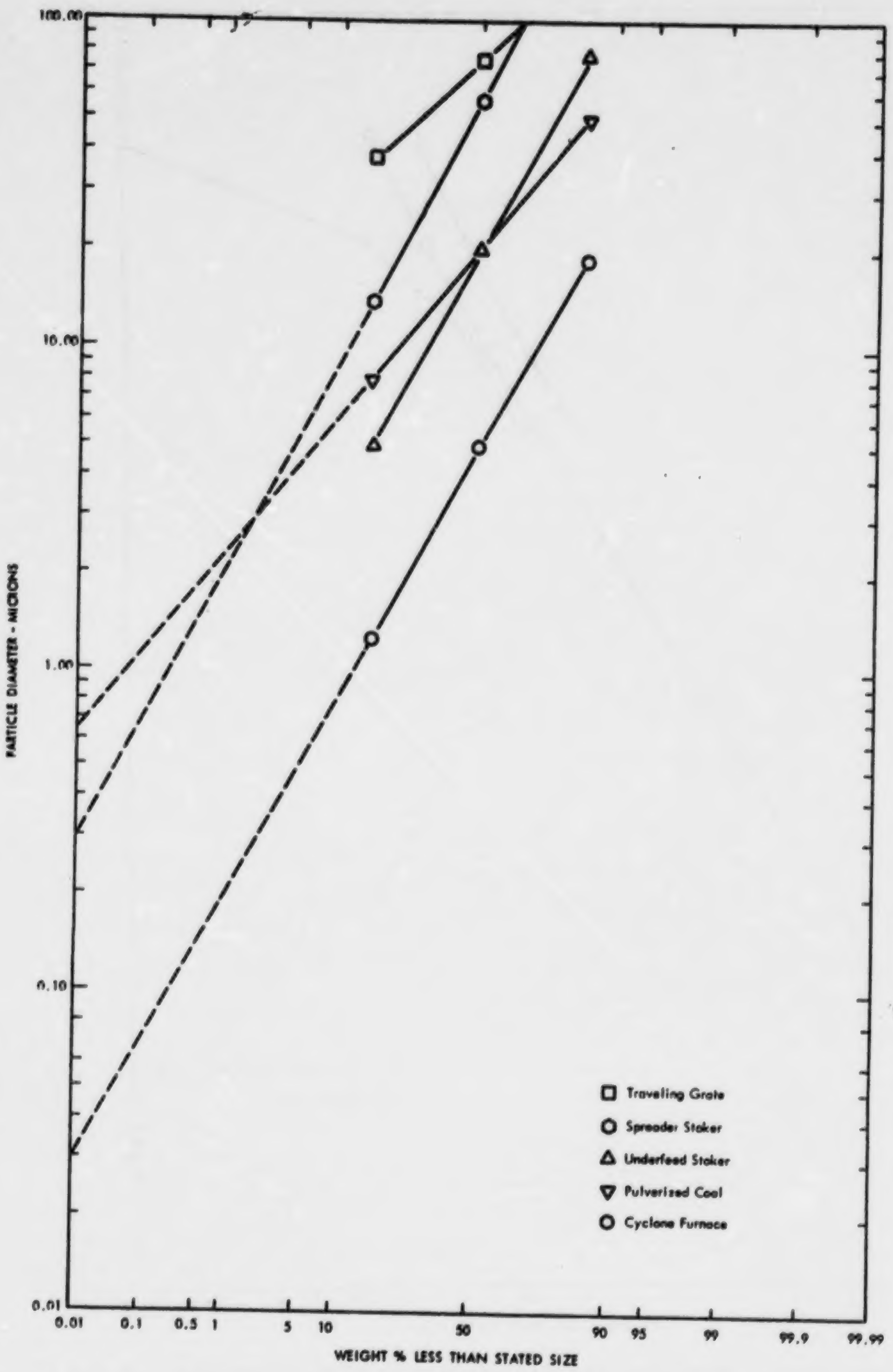

Figure A-22. Particle-size distributions of particulates emitted from uncontrolled industrial power plants (coal-fired)

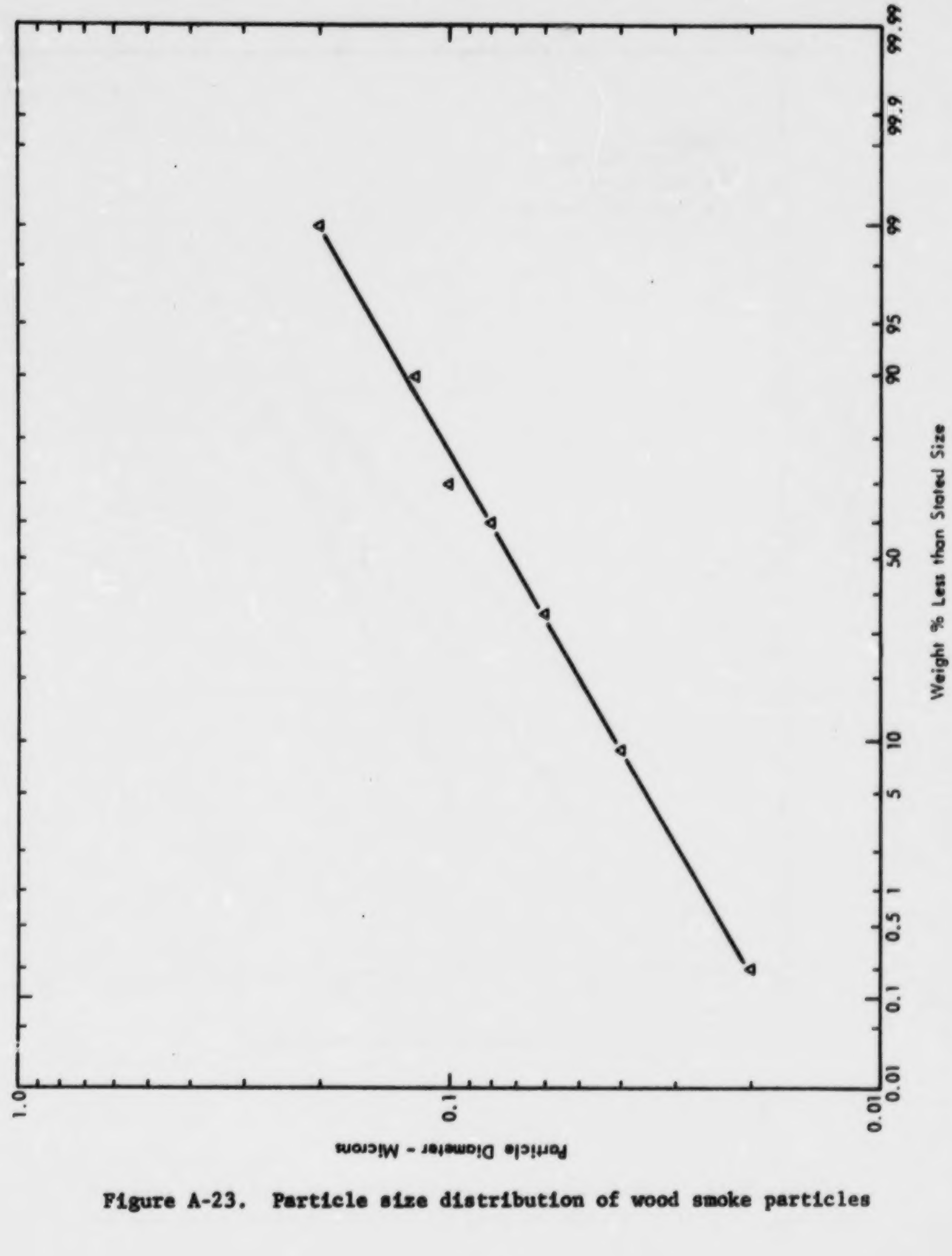

Figure A-23. Particle size distribution of wood smoke particles

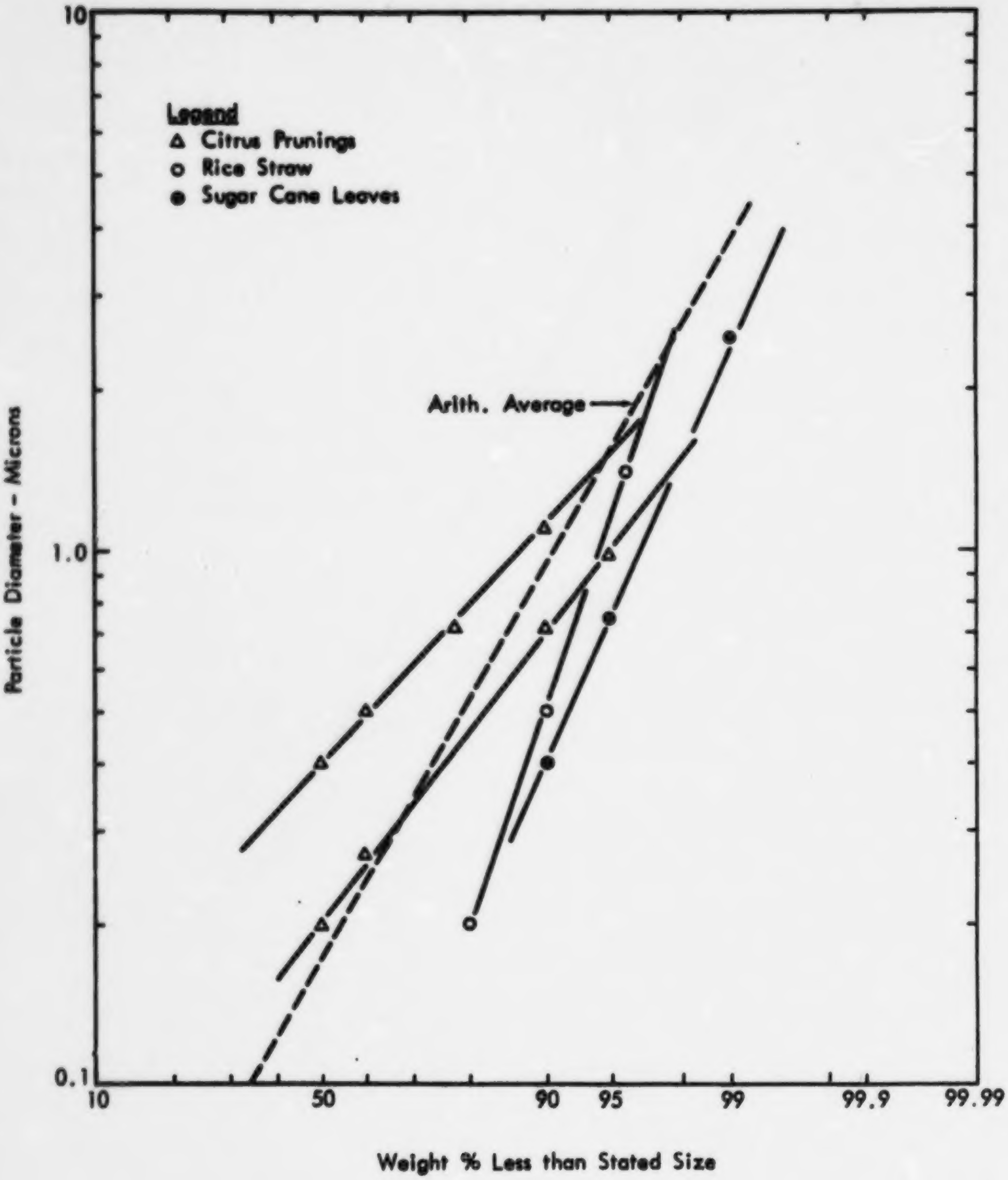

Figure A-24. Particle-size distributions of particles generated by the burning of various agricultural wastes

APPENDIX B

DATA SHEETS

Table B-1. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ASPHALT DRYERS
(tons/year)

Source - Asphalt, hot mix

Process - Dryers

	Distribution of Emissions					
		Controlled				
Particle Size Range (μ)	Uncontrolled	Cyclone	Cyclone and Scrubber	Cyclone and Fabric Filter		Total Emissions
3-7	11,970	13,272	10,833	11		36,086
1-3	8,253	13,459	116,777	543		139,032
0.5-1.0	1,386	2,662	46,930	383		51,361
0.1-0.5	435	852	25,853	225		27,365
0.05-0.1	6	12	486	4		508
0.01-0.05						
Total Emissions	22,050	30,257	200,879	1,166		254,352

Table B-2. DISTRIBUTION OF PROCESS EMISSIONS FROM ASPHALT DRYERS

Source - Asphalt, hot mix

Process - Dryers

Process Emissions = Production (tons/year)[a] (350×10^6) Emission Factor[a] (lb/ton) (36) $\left(\frac{1}{2,000}\right)$ = 6,300,000 tons/year

Application of Control = 99 % [c]

Process Emissions into Uncontrolled Plants = 63,000 tons/year

Process Emissions into Controlled Plants = 6,237,000 tons/year

Type of Control Device	% Application on Controlled Plants[d]	Process Emissions Into Control Device (tons/year)
Cyclone	2	124,740
Cyclone and scrubber	82	5,114,340
Cyclone and FF	16	997,920

---

a/ John Gray, National Asphalt Pavers Association.

b/ Reference 12 gives 45 lb/ton total emissions 80% is from dryers and 20% from vent lines Ref. 2.

c/ Reference 2.

d/ Same as a/, for fabric filter others estimated.

Table B-3. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ASPHALT DRYERS

Process - Asphalt dryers

Control Device - Uncontrolled

Process Emissions into Control Device 63,000 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	19.0	100		11,970
1-3	13.1	100		8,253
0.5-1.0	2.2	100		1,386
0.1-0.5	0.69	100		435
0.05-0.1	0.01	100		6
0.01-0.05				
Total	35.00			22,050

Table B-4. FINE-PARTICLE EMISSIONS FROM ASPHALT DRYERS CONTROLLED BY CYCLONES

Process - Asphalt dryers

Control Device - Cyclones

Process Emissions into Control Device 124,740 tons/year

Process Emissions		Control Device Cyclone [a]	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	19.0	56		13,272
1-3	13.1	83		13,459
0.5-1.0	2.2	97		2,662
0.1-0.5	0.69	99		852
0.05-0.1	0.01	100		12
0.01-0.05				
Total	35.00			30,257

---

[a] From medium efficiency cyclone curve.

Table B-5. FINE-PARTICLE EMISSIONS FROM ASPHALT DRYERS CONTROLLED BY CYCLONES PLUS SCRUBBERS

Process - Asphalt dryer

Control Device - Cyclone plus scrubber

Process Emissions into Control Device 5,114,340 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone[a] Penetration (%) (1 - efficiency)	Control Device Scrubber[b] Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	19.0	56	2	10,833
1-3	13.1	83	21	116,777
0.5-1.0	2.2	97	43	46,930
0.1-0.5	0.69	99	74	25,853
0.05-0.1	0.01	100	95	486
0.01-0.05				
Total	35.00			200,879

---

a/ From medium efficiency cyclone curve.

b/ From medium efficiency wet scrubber curve.

Table B-6. FINE-PARTICLE EMISSIONS FROM ASPHALT DRYERS CONTROLLED BY CYCLONES PLUS FABRIC FILTERS

Process - Asphalt dryer

Control Device - Cyclones plus fabric filters

Process Emissions into Control Device 997,920 tons/year

Process Emissions Size (µ)	Percent	Control Device Cyclone[a] Penetration (%) (1 - efficiency)	Control Device Fabric filter[b] Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	19.0	56	0.01	11
1-3	13.1	83	0.5	543
0.5-1.0	2.2	97	1.8	383
0.1-0.5	0.69	99	3.3	225
0.05-0.1	0.01	100	4.2	4
0.01-0.05				
Total	35.00			1,166

---

[a] From medium efficiency cyclone curve.

[b] From fabric filter fractional efficiency curve.

Table B-7. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ASPHALT VENT LINES
(tons/year)

Source - Asphalt, hot mix

Process - Vent lines

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	Cyclone and Scrubber	Cyclone and Fabric Filter		
3-7	3,654	4,052	3,322	3		11,031
1-3	1,158	1,902	16,380	76		19,516
0.5-1.0	65	124	2,187	18		2,394
0.1-0.5	6	12	375	3		396
0.05-0.1						
0.01-0.05						
Total Emissions	4,883	6,090	22,264	100		33,337

Table B-8. DISTRIBUTION OF PROCESS EMISSIONS FROM ASPHALT VENT LINES

Source - Asphalt, hot mix

Process - Vent lines

Process Emissions = $\underset{(350 \times 10^6)}{\text{Production (tons/year)}} \quad \underset{(9)}{\text{Emission Factor (lb/ton)}} \quad \left(\frac{1}{2,000}\right)$ = 1,575,000 tons/year

Application of Control = 99 %

Process Emissions into Uncontrolled Plants = 15,750 tons/year

Process Emissions into Controlled Plants = 1,559,250 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclone	2	31,185
Cyclone and scrubber	82	1,278,585
Cyclone and fabric filter	16	249,480

Table B-9. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ASPHALT VENT LINES

Process - Asphalt vent lines

Control Device - Uncontrolled

Process Emissions into Control Device 15,750 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	23.2	100		3,654
1-3	7.35	100		1,158
0.5-1.0	0.41	100		65
0.1-0.5	0.04	100		6
0.05-0.1				
0.01-0.05				
Total	31.00			4,883

Table B-10. FINE-PARTICLE EMISSIONS FROM VENT LINES CONTROLLED BY CYCLONES

Process - Asphalt vent lines

Control Device - Cyclones

Process Emissions into Control Device 31,185 tons/year

Process Emissions Size (μ)	 Percent	Control Device Cyclones Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	23.2	56		4,052
1-3	7.35	83		1,902
0.5-1.0	0.41	97		124
0.1-0.5	0.04	99		12
0.05-0.1				
0.01-0.05				
Total	31.00			6,090

Table B-11. FINE-PARTICLE EMISSIONS FROM ASPHALT VENT LINES
CONTROLLED BY CYCLONES PLUS SCRUBBERS

Process - Asphalt vent lines

Control Device - Cyclones plus scrubber

Process Emissions into Control Device 1,278,585 tons/year

Process Emissions		Control Device Cyclone	Control Device Scrubber	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	23.2	56	2	3,322
1-3	7.35	83	21	16,380
0.5-1.0	0.41	97	43	2,187
0.1-0.5	0.04	99	74	375
0.05-0.1				
0.01-0.05				
Total	31.00			22,264

Table B-12. FINE-PARTICLE EMISSIONS FROM ASPHALT VENT LINES CONTROLLED BY CYCLONES PLUS FABRIC FILTERS

Process - Asphalt vent lines

Control Device - Cyclones plus fabric filters

Process Emissions into Control Device 249,480 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%) (1 - efficiency)	Control Device Fabric Filter Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	23.2	56	0.01	3
1-3	7.35	83	0.5	76
0.5-1.0	0.41	97	1.8	18
0.1-0.5	0.04	99	3.3	3
0.05-0.1				
0.01-0.05				
Total	31.00			100

Table B-13. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ROTARY CEMENT KILNS
(tons/year)

Source - Cement plants

Process - Rotary kilns

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	ESP	Cyclone & ESP	Fabric	
3-7	22,770	35,703	39,050	4,999	22	102,544
1-3	14,214	39,699	38,306	8,734	697	101,650
0.5-1.0	2,277	9,149	9,484	3,110	401	24,421
0.1-0.5	745	3,432	5,294	1,991	241	11,703
0.05-0.1	14	68	139	56	6	283
0.01-0.05						
Total Emissions	40,020	88,051	92,273	18,890	1,367	240,601

Table B-14. DISTRIBUTION OF PROCESS EMISSIONS FROM ROTARY CEMENT KILNS

Source - Cement plant

Process - Rotary kilns

$$\text{Process Emissions} = \underset{\text{(tons/year)}^{a/}}{\overset{\text{Production}}{(82.6 \times 10^6)}} \quad \underset{\text{(lb/ton)}}{\overset{\text{Emission Factor}}{(167)}} \overset{b/}{\left(\frac{1}{2{,}000}\right)} = 6{,}900{,}000 \text{ tons/year}$$

Application of Control = 98 % c/

Process Emissions into Uncontrolled Plants = 138,000 tons/year

Process Emissions into Controlled Plants =6,762,000 tons/year

Type of Control Device	% Application on Controlled Plants[d]	Process Emissions Into Control Device (tons/year)
Cyclone	10	676,200
ESP	50	3,381,000
Cyclone and ESP	20	1,352,400
Fabric filter	20	1,352,400

---

a/ Survey of current business, July 1973.

b/ Geometric mean of available data.

c/ Estimate of current application (based on 94.5% in 1968).

d/ Estimated present values based on 1968 telephone survey and indicated trends.

Table B-15. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED CEMENT KILNS

Process - Cement kilns

Control Device - Uncontrolled

Process Emissions into Control Device 138,000 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16.5	100		22,770
1-3	10.3	100		14,214
0.5-1.0	1.65	100		2,277
0.1-0.5	0.54	100		745
0.05-0.1	0.01	100		14
0.01-0.05				
Total	29.00			40,020

Table B-16. FINE-PARTICLE EMISSIONS FROM CEMENT KILNS CONTROLLED BY CYCLONES

Process - Cement kilns

Control Device - Cyclones

Process Emissions into Control Device 676,200 tons/year

Process Emissions		Control Device Cyclones Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
Size (μ)	Percent			
3-7	16.5	32		35,703
1-3	10.3	57		39,699
0.5-1.0	1.65	82		9,149
0.1-0.5	0.54	94		3,432
0.05-0.1	0.01	100		68
0.01-0.05				
Total	29.00			88,051

Table B-17. FINE-PARTICLE EMISSIONS FROM CEMENT KILNS CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Cement kilns

Control Device - ESP

Process Emissions into Control Device 3,381,000 tons/year

Process Emissions		Control Device ESP	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16.5	7		39,050
1-3	10.3	11		38,306
0.5-1.0	1.65	17		9,484
0.1-0.5	0.54	29		5,294
0.05-0.1	0.01	41		139
0.01-0.05				
Total	29.00			92,273

Table B-18. FINE-PARTICLE EMISSIONS FROM CEMENT KILNS CONTROLLED BY CYCLONES PLUS ELECTROSTATIC PRECIPITATORS

Process - Cement kilns

Control Device - Cyclones and ESP

Process Emissions into Control Device 1,352,400 tons/year

		Control Device Cyclone	Control Device ESP	
Process Emissions Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16.5	32	7	4,999
1-3	10.3	57	11	8,734
0.5-1.0	1.65	82	17	3,110
0.1-0.5	0.54	94	29	1,991
0.05-0.1	0.01	100	41	56
0.01-0.05				
Total	29.00			18,890

Table B-19. FINE-PARTICLE EMISSIONS FROM CEMENT KILNS CONTROLLED BY FABRIC FILTERS

Process - Cement kilns

Control Device - Fabric filter

Process Emissions into Control Device 1,352,400 tons/year

		Control Device	Control Device	
		Fabric filter		
Process Emissions		Penetration (%)	Penetration (%)	Emissions
Size (μ)	Percent	(1 - efficiency)	(1 - efficiency)	(tons/year)
3-7	16.5	0.01		22
1-3	10.3	0.50		697
0.5-1.0	1.65	1.8		401
0.1-0.5	0.54	3.3		241
0.05-0.1	0.01	4.2		6
0.01-0.05				
Total	29.00			1,367

Table B-20. SUMMARY OF FINE-PARTICLE EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROSILICON ALLOYS
(tons/year)

Source - Ferroalloy electric furnace

Process - Ferrosilicon alloys

Particle Size Range (µ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Wet Scrubber	Fabric Filter			
3-7	1,885	7	--			1,892
1-3	18,845	126	24			18,995
0.5-1.0	28,268	271	127			28,666
0.1-0.5	81,663	1,293	674			83,630
0.05-0.1	17,275	396	181			17,852
0.01-0.05	7,852	268	86			8,206
Total Emissions	155,788	2,361	1,092			159,241

Table B-21. DISTRIBUTION OF PROCESS EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROSILICON ALLOYS[a]

Source - Ferroalloy electric furnace

Process - Ferrosilicon alloys

	Production[a] (tons/year)	Emission Factor[a] (lb/ton)		
Process Emissions =	(865,000)	( )	$\left(\frac{1}{2,000}\right)$	= 261,740 tons/year[a]

Application of Control = 40 % [b]

Process Emissions into Uncontrolled Plants = 157,044 tons/year

Process Emissions into Controlled Plants = 104,696 tons/year

Type of Control Device	% Application on[b] Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubbers	62.5	65,435
Fabric filters	37.5	39,261

---

[a] The process emissions are calculated as a composite for the following alloys.

	Production (ton/year)		Emission Factor (lb/ton)		Process Emissions (ton/year)
Silvery pig iron	165,000	x	$116 \times \frac{1}{2,000}$	=	9,570
50% FeSi	440,000		$446 \times \frac{1}{2,000}$	=	98,120
60-75% FeSi	140,000		$915 \times \frac{1}{2,000}$	=	64,050
Si metal	120,000		$1,500 \times \frac{1}{2,000}$	=	90,000
	865,000				261,740

[b] Based on 1970 ferroalloy emission control survey which covered 40 furnaces which produced ferrosilicon alloys.

Table B-22. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROSILICON ALLOYS[a]

Process - Ferroalloy electric furnace

Control Device - Uncontrolled

Process Emissions into Control Device 157,044 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	1.2	100		1,885
1-3	12.0	100		18,845
0.5-1.0	18.0	100		28,268
0.1-0.5	52.0	100		81,663
0.05-0.1	11.0	100		17,275
0.01-0.05	5.0	100		7,852
Total	99.2			155,788

---

[a] See distribution table note a.

Table B-23. FINE-PARTICLE EMISSIONS FROM WET SCRUBBER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROSILICON ALLOYS[a]

Process - Ferroalloy electric furnace

Control Device - Wet scrubber[b]

Process Emissions into Control Device 65,435 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Wet scrubber Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	1.2	0.9		7
1-3	12.0	1.6		126
0.5-1.0	18.0	2.3		271
0.1-0.5	52.0	3.8		1,293
0.05-0.1	11.0	5.5		396
0.01-0.05	5.0	8.2		268
Total	99.2			2,361

---

a/ See distribution table note a.

b/ Includes high energy wet scrubbers, disintegrator scrubbers, electrostatic precipitators with water sprays, etc.

c/ Efficiency values assumed equal to high efficiency electrostatic precipitator.

Table B-24. FINE-PARTICLE EMISSIONS FROM FABRIC FILTER CONTROLLED FERRO-ALLOY ELECTRIC FURNACES PRODUCING FERROSILICON ALLOYS[a]

Process - Ferroalloy electric furnace

Control Device - Fabric filter

Process Emissions into Control Device 39,261 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Fabric filter Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	1.2	0.01		--
1-3	12.0	0.5		24
0.5-1.0	18.0	1.8		127
0.1-0.5	52.0	3.3		674
0.05-0.1	11.0	4.2		181
0.01-0.05	5.0	4.4		86
Total	99.2			1,092

---

a/ See distribution table note a.

Table B-25. SUMMARY OF FINE-PARTICLE EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROMANGANESE ALLOYS
(tons/year)

Source - Ferroalloy electric furnace

Process - Ferromanganese alloys

	Distribution of Emissions					
		Controlled				
Particle Size Range (µ)	Uncontrolled	Wet Scrubber	Fabric Filter			Total Emissions
3-7	3,125	33	--			3,158
1-3	15,464	290	30			15,784
0.5-1.0	9,278	250	65			9,593
0.1-0.5	4,372	195	56			4,623
0.05-0.1	23	1				24
0.01-0.05						
Total Emissions	32,262	769	151			33,182

Table B-26. DISTRIBUTION OF PROCESS EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROMANGANESE ALLOYS[a]

Source - Ferroalloy electric furnaces

Process - Ferromanganese alloys

	Production[a] (tons/year)	Emission Factor[a] (lb/ton)		
Process Emissions =	(570,000)	( )	$\left(\frac{1}{2,000}\right)$	= 83,475 tons/year[a]

Application of Control = 61 % [b]

Process Emissions into Uncontrolled Plants = 32,555 tons/year

Process Emissions into Controlled Plants = 50,920 tons/year

Type of Control Device	% Application on[b] Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubbers	75	38,190
Fabric filters	25	12,730

---

a/ The process emissions are calculated as a composite for the following alloys.

	Production (ton/year)		Emission Factor (lb/ton)		Process Emissions
Ferromanganese	330,000	x	$335 \times \frac{1}{2,000}$	=	55,275
Silicomanganese	200,000		$219 \times \frac{1}{2,000}$	=	21,900
Ferromanganese silicon	40,000		$315 \times \frac{1}{2,000}$	=	6,300
SMZ	Neglect		Unknown	=	0
	570,000				83,475

b/ Based on 1970 ferroalloy emission control survey which covered 33 furnaces which produced ferromanganese alloys.

Table B-27. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROMANGANESE ALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Uncontrolled

Process Emissions into Control Device 32,555 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.6	100		3,125
1-3	47.5	100		15,464
0.5-1.0	28.5	100		9,278
0.1-0.5	13.43	100		4,372
0.05-0.1	0.07	100		23
0.01-0.05	0	100		--
Total	99.10			32,262

---

a/ See distribution table note a.

Table B-28. FINE-PARTICLE EMISSIONS FROM WET SCRUBBER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROMANGANESE ALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Wet scrubbers[b]

Process Emissions into Control Device 38,190 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Wet scrubber Penetration (%) (1 - efficiency)[c]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.6	0.9		33
1-3	47.5	1.6		290
0.5-1.0	28.5	2.3		250
0.1-0.5	13.43	3.8		195
0.05-0.1	0.07	5.5		1
0.01-0.05	0.0	8.2		--
Total	99.10			769

---

[a] See distribution table note a.

[b] Includes high energy wet scrubbers, disintegrator scrubbers, electrostatic precipitators with water sprays, etc.

[c] Efficiency values assumed equal to high efficiency electrostatic precipitator.

Table B-29. FINE-PARTICLE EMISSIONS FROM FABRIC FILTER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROMANGANESE ALLOYS[a]

Process - Ferroalloy electric furnace

Control Device - Fabric filter

Process Emissions into Control Device 12,730 tons/year

Process Emissions Size (μ)	Percent	Control Device Fabric filter Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.6	0.01		--
1-3	47.5	0.5		30
0.5-1.0	28.5	1.8		65
0.1-0.5	13.43	3.3		56
0.05-0.1	0.07	4.2		--
0.01-0.05	0	4.4		--
Total	99.10			151

---

[a] See distribution table note a.

Table B-30. SUMMARY OF FINE-PARTICLE EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROCHROMIUM ALLOYS[a]

(tons/year)

Source - Ferroalloy electric furnaces

Process - Ferrochromium alloys

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Wet Scrubbers				
3-7	10,955	20				10,975
1-3	22,693	74				22,767
0.5-1.0	14,477	68				14,545
0.1-0.5	18,780	146				18,926
0.05-0.1	1,956	22				1,978
0.01-0.05	783	13				796
Total Emissions	69,644	343				69,987

Table B-31. DISTRIBUTION OF PROCESS EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING FERROCHROMIUM ALLOYS[a]

Source - Ferroalloy electric furnaces

Process - Ferrochromium alloys

	Production[a] (tons/year)	Emission Factor[a] (lb/ton)		
Process Emissions =	(400,000)	( )	$\left(\frac{1}{2,000}\right)$	= 94,280 tons/year[a]

Application of Control = 17 %[b]

Process Emissions into Uncontrolled Plants = 78,252 tons/year

Process Emissions into Controlled Plants = 16,028 tons/year

Type of Control Device	% Application on Controlled Plants[b]	Process Emissions Into Control Device (tons/year)
Wet scrubbers	100	16,028

---

[a]

Alloy	Production (ton/year)		Emission Factor (lb/ton)		Process Emissions (ton/year)
Ferrochromium	290,000	x	$335 \times \frac{1}{2,000}$	=	48,575
Ferrochrom silicon and other chrome alloys	110,000	x	$831 \times \frac{1}{2,000}$	=	45,705
	400,000				94,280

[b] Based on 1970 ferroalloy emission control survey which covered 30 furnaces producing ferrochromium alloys.

Table B-32. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROCHROMIUM ALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Uncontrolled

Process Emissions into Control Device 78,252 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	14	100		10,955
1-3	29	100		22,693
0.5-1.0	18.5	100		14,477
0.1-0.5	24.0	100		18,780
0.05-0.1	2.5	100		1,956
0.01-0.05	1.0	100		783
Total	89.0			69,644

---

[a] See distribution table note a.

Table B-33. FINE-PARTICLE EMISSIONS FROM WET SCRUBBER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING FERROCHROMIUM ALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Wet scrubbers[b]

Process Emissions into Control Device 16,028 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Wet scrubber Penetration (%) (1 - efficiency)[c]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	14	0.9		20
1-3	29	1.6		74
0.5-1.0	18.5	2.3		68
0.1-0.5	24.0	3.8		146
0.05-0.1	2.5	5.5		22
0.01-0.05	1.0	8.2		13
Total	89.0			343

---

[a] See distribution table note a.

[b] Includes high energy wet scrubbers, disintegrator scrubbers, electrostatic precipitating with water sprays, etc.

[c] Efficiency values assumed equal to high efficiency electrostatic precipitator.

Table B-34. SUMMARY OF FINE-PARTICLE EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING MISCELLANEOUS FERROALLOYS
(tons/year)

Source - Ferroalloy electric furnace

Process - Miscellaneous alloys

Particle Size Range (µ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Wet Scrubber	Fabric Filter			
3-7	3,830	18	--			3,848
1-3	11,894	97	9			12,000
0.5-1.0	9,274	109	26			9,409
0.1-0.5	12,701	246	65			13,012
0.05-0.1	1,048	29	7			1,084
0.01-0.05	363	15	2			380
Total Emissions	39,110	514	109			39,733

Table B-35. DISTRIBUTION OF PROCESS EMISSIONS FROM FERROALLOY ELECTRIC FURNACES PRODUCING MISCELLANEOUS FERROALLOYS[a]

Source - Ferroalloy electric furnace

Process - Miscellaneous alloys

Process Emissions = Production[a] (tons/year) (280,000) Emission Factor[b] (lb/ton) (480) $\left(\frac{1}{2,000}\right)$ = 67,200 tons/year

Application of Control = 40%[c]

Process Emissions into Uncontrolled Plants = 40,320 tons/year

Process Emissions into Controlled Plants = 26,880 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubbers	76.6	20,590
Fabric filters	23.4	6,290

---

[a] Difference between total electric furnace ferroalloy production of 2,115,000 tons/year and 1,835,000 tons/year covered separately by ferrosilicon, ferromanganese, and ferrochromium calculations.

[b] Geometric average of all known emission factors and alloy production.

[c] Based on 1970 ferroalloy emission control survey which covered 112 furnaces producing all ferroalloys.

Table B-36. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING MISCELLANEOUS FERROALLOYS[a]

Process - Ferroalloy electric furnace

Control Device - Uncontrolled

Process Emissions into Control Device 40,320 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.5	100		3,830
1-3	29.5	100		11,894
0.5-1.0	23.0	100		9,274
0.1-0.5	31.5	100		12,701
0.05-0.1	2.6	100		1,048
0.01-0.05	0.9	100		363
Total	97.0			39,110

---

a/ See distribution of process emissions note a.

Table B-37. FINE-PARTICLE EMISSIONS FROM WET SCRUBBER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING MISCELLANEOUS FERROALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Wet scrubbers[b]

Process Emissions into Control Device 20,590 tons/year

Process Emissions		Control Device Wet scrubber	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.5	0.9		18
1-3	29.5	1.6		97
0.5-1.0	23.0	2.3		109
0.1-0.5	31.5	3.8		246
0.05-0.1	2.6	5.5		29
0.01-0.05	0.9	8.2		15
Total	97.0			514

---

a/ See distribution table note a.

b/ Includes high energy wet scrubbers, disintegrator scrubbers, electrostatic precipitators with water sprays, etc.

c/ Efficiency values assumed equal to high efficiency electrostatic precipitator.

Table B-38. FINE-PARTICLE EMISSIONS FROM FABRIC FILTER CONTROLLED FERROALLOY ELECTRIC FURNACES PRODUCING MISCELLANEOUS FERROALLOYS[a]

Process - Ferroalloy electric furnaces

Control Device - Fabric filters

Process Emissions into Control Device 6,290 tons/year

Process Emissions Size (μ)	Percent	Control Device Fabric filter Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	9.5	0.01		--
1-3	29.5	0.5		9
0.5-1.0	23.0	1.8		26
0.1-0.5	31.5	3.3		65
0.05-0.1	2.6	4.2		7
0.01-0.05	0.9	4.4		2
Total	97.0			109

---

[a] See distribution table note a.

Table B-39. SUMMARY OF FINE-PARTICLE EMISSIONS FROM FERTILIZER GRANULATION AND DRYING

(tons/year)

Source - Fertilizer

Process - Granulation and drying

	Distribution of Emissions					
		Controlled				
Particle Size Range (μ)	Uncontrolled	Scrubber				Total Emissions
3-7	3,822	1,452				5,274
1-3	1,739	6,939				8,678
0.5-1.0	411	3,357				3,768
0.1-0.5	220	3,090				3,310
0.05-0.1	19	345				364
0.01-0.05	0	0				0
Total Emissions	6,211	15,183				21,394

Table B-40. DISTRIBUTION OF PROCESS EMISSIONS FROM FERTILIZER GRANULATION AND DRYING

Source - Fertilizer

Process - Granulation and drying

Process Emissions = Production (tons/year) (19.6×10^6) Emission Factor (lb/ton) (195) $\left(\frac{1}{2,000}\right)$ = 1,911,000 tons/year

Application of Control = 95 %

Process Emissions into Uncontrolled Plants = 95,550 tons/year

Process Emissions into Controlled Plants = 1,815,450 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubbers	100	1,815,450

Table B-41. FINE-PARTICLE EMISSIONS FROM FERTILIZER GRANULATION AND DRYING CONTROLLED BY WET SCRUBBERS

Process - Fertilizer granulation and drying

Control Device - Wet scrubbers

Process Emissions into Control Device 1,815,450 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Scrubbers Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	4.0	2		1,452
1-3	1.82	21		6,939
0.5-1.0	0.43	43		3,357
0.1-0.5	0.23	74		3,090
0.05-0.1	0.02	95		345
0.01-0.05	0	100		0
Total	6.5			15,183

---

a/ Efficiency values were taken from medium fractional efficiency curve.

Table B-42. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED FERTILIZER GRANULATION AND DRYING

Process - Fertilizer granulation and drying

Control Device - Uncontrolled

Process Emissions into Control Device 95,550 tons/year

Process Emissions		Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
Size (μ)	Percent			
3-7	4.0	100		3,822
1-3	1.82	100		1,739
0.5-1.0	0.43	100		411
0.1-0.5	0.23	100		220
0.05-0.1	0.02	100		19
0.01-0.05	0	100		0
Total	6.5			6,211

Table B-43. SUMMARY OF FINE-PARTICLE EMISSIONS FROM BASIC OXYGEN FURNACES, IRON AND STEEL

(tons/year)

Source - Iron and steel

Process - Basic oxygen furnace

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
	Uncontrolled	Controlled				
		ESP	Cyclone	Venturi	FF	
3-7		--		--		--
1-3		802		969		1,771
0.5-1.0		6,917		32,394		39,311
0.1-0.5		18,348		300,057		318,405
0.05-0.1		92		1,984		2,076
0.01-0.05		--		--		--
Total Emissions		26,159		335,404		361,563

Table B-44. DISTRIBUTION OF PROCESS EMISSIONS FROM BASIC OXYGEN FURNACE

Source - Iron and steel

Process - BOF

Process Emissions = Production (tons/year) (78 x 10^6) Emission Factor (lb/ton) (51) $\left(\frac{1}{2,000}\right)$ = 1,989,000 tons/year

Application of Control = 100 %

Process Emissions into Uncontrolled Plants = 0 tons/year

Process Emissions into Controlled Plants = 1,989,000 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	42	835,380
Venturi	58	1,153,620

Table B-45. FINE-PARTICLE EMISSIONS FROM BASIC OXYGEN FURNACES CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Basic oxygen furnace

Control Device - Electrostatic precipitator

Process Emissions into Control Device 835,380 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device ESP Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	0	0.9		--
1-3	6	1.6		802
0.5-1.0	36	2.3		6,917
0.1-0.5	57.8	3.8		18,348
0.05-0.1	0.2	5.5		92
0.01-0.05	--	8.2		--
Total	100			26,159

---

[a] Efficiency values were taken from high fractional efficiency curve.

Table B-46. FINE-PARTICLE EMISSIONS FROM BASIC OXYGEN FURNACES CONTROLLED BY VENTURI SCRUBBER

Process - Basic oxygen furnace

Control Device - Venturi scrubber

Process Emissions into Control Device 1,153,620 tons/year

Process Emissions Size (μ)	Percent	Control Device Venturi Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	0	0.02		--
1-3	6	1.4		969
0.5-1.0	36	7.8		32,394
0.1-0.5	57.8	45		300,057
0.05-0.1	0.2	86		1,984
0.01-0.05	--	--		--
Total	100			335,404

Table B-47. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC ARC FURNACE, IRON AND STEEL
(tons/year)

Source - Iron and steel

Process - Electric arc furnace

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP	Cyclone	Wet Scrubber	FF	
3-7	3,140	7	none	--	1	3,148
1-3	4,830	20		180	74	5,104
0.5-1.0	2,898	18		312	161	3,389
0.1-0.5	5,072	51		1,301	516	6,940
0.05-0.1	1,449	21		552	188	2,210
0.01-0.05	1,691	37		686	235	2,649
Total Emissions	19,080	154		3,031	1,175	23,440

Table B-48. DISTRIBUTION OF PROCESS EMISSIONS FROM ELECTRIC ARC FURNACE

Source - Iron and steel

Process - Electric arc furnace

Process Emissions = Production (tons/year) (23×10^6) Emission Factor (lb/ton) (10) $\left(\frac{1}{2,000}\right)$ = 115,000 tons/year

Application of Control = 79 %

Process Emissions into Uncontrolled Plants = 24,150 tons/year

Process Emissions into Controlled Plants = 90,850 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubber	11	9,994
ESP	7	6,359
FF	82	74,497

Table B-49. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ELECTRIC ARC FURNACES

Process - Electric arc furnace

Control Device - Uncontrolled

Process Emissions into Control Device 24,150 tons/year

Process Emissions		Control Device Uncontrolled Penetration (%)	Control Device Penetration (%)	Emissions
Size (μ)	Percent	(1 - efficiency)	(1 - efficiency)	(tons/year)
3-7	13	100		3,140
1-3	20	100		4,830
0.5-1.0	12	100		2,898
0.1-0.5	21	100		5,072
0.05-0.1	6	100		1,449
0.01-0.05	7	100		1,691
Total	79			19,080

Table B-50. FINE-PARTICLE EMISSIONS FROM ELECTRIC ARC FURNACES CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Electric arc furnace

Control Device - Electrostatic precipitator

Process Emissions into Control Device 6,359 tons/year

Process Emissions Size (µ)	Percent	Control Device ESP Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	13	0.9		7
1-3	20	1.6		20
0.5-1.0	12	2.3		18
0.1-0.5	21	3.8		51
0.05-0.1	6	5.5		21
0.01-0.05	7	8.2		37
Total	79			154

---

[a] Efficiency valves were taken from high fractional efficiency curve.

Table B-51. FINE-PARTICLE EMISSIONS FROM ELECTRIC ARC FURNACES CONTROLLED BY WET SCRUBBER

Process - Electric arc furnaces

Control Device - Wet scrubber

Process Emissions into Control Device 9,994 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Wet scrubber Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	13	0.03		--
1-3	20	9		180
0.5-1.0	12	26		312
0.1-0.5	21	62		1,301
0.05-0.1	6	92		552
0.01-0.05	7	98		686
Total	79			3,031

---

[a] Efficiency values were taken from high fractional efficiency curve.

Table B-52. FINE-PARTICLE EMISSIONS FROM ELECTRIC ARC FURNACES
CONTROLLED BY FABRIC FILTER

Process - Electric arc furnace

Control Device - Fabric filter

Process Emissions into Control Device 74,497 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device FF Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	13	0.01		1
1-3	20	0.5		74
0.5-1.0	12	1.8		161
0.1-0.5	21	3.3		516
0.05-0.1	6	4.2		188
0.01-0.05	7	4.5		235
Total	79			1,175

Table B-53. SUMMARY OF FINE-PARTICLE EMISSIONS FROM OPEN HEARTH FURNACES

(tons/year)

Source - Iron and steel

Process - Open hearth furnace

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP				
3-7	530	210				740
1-3	4,162	2,594				6,756
0.5-1.0	9,384	9,040				18,424
0.1-0.5	24,072	39,558				63,630
0.05-0.1	2,122	4,929				7,051
0.01-0.05	326	1,017				1,343
Total Emissions	40,596	57,348				97,944

Table B-54. DISTRIBUTION OF PROCESS EMISSIONS FROM OPEN HEARTH FURNACES

Source - Iron and steel

Process - Open hearth furnace

Process Emissions = Production[a] (tons/year) (32×10^6) Emission Factor (lb/ton) (17) $\left(\frac{1}{2,000}\right)$ = 272,000 tons/year

Application of Control = 85 %

Process Emissions into Uncontrolled Plants = 40,800 tons/year

Process Emissions into Controlled Plants = 231,200 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	100	231,200

---

[a] Estimate based on 1968-1971 trend.

Table B-55. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED OPEN HEARTH FURNACES

Process - Open hearth furnaces

Control Device - Uncontrolled

Process Emissions into Control Device 40,800 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	1.3	100		530
1-3	10.2	100		4,162
0.5-1.0	23.0	100		9,384
0.1-0.5	59.0	100		24,072
0.05-0.1	5.2	100		2,122
0.01-0.05	0.8	100		326
Total	99.5			40,596

Table B-56. FINE-PARTICLE EMISSIONS FROM OPEN HEARTH FURNACES CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Open hearth furnaces

Control Device - Electrostatic precipitators

Process Emissions into Control Device 231,200 tons/year

Process Emissions		Control Device ESP a/	Control Device	Emissions
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	(tons/year)
3-7	1.3	7		210
1-3	10.2	11		2,594
0.5-1.0	23.0	17		9,040
0.1-0.5	59.0	29		39,558
0.05-0.1	5.2	41		4,929
0.01-0.05	0.8	55		1,017
Total	99.5			57,348

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-57. SUMMARY OF FINE-PARTICLE EMISSIONS FROM IRON AND STEEL PLANT SINTER MACHINE WINDBOXES
(tons/year)

Source - Iron and steel plant

Process - Sinter machine windboxes

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	Cyclone and ESP	Fabric Filter		
3-7	0	3,456	242	1		3,699
1-3	0	3,324	366	15		3,705
0.5-1.0	0	992	169	11		1,172
0.1-0.5	0	487	141	9		637
0.05-0.1	0					
0.01-0.05						
Total Emissions	0	8,259	918	36		9,213

Table B-58. DISTRIBUTION OF PROCESS EMISSIONS FROM IRON AND STEEL PLANT SINTER MACHINE WINDBOXES

Source - Iron and steel

Process - Sinter machine windboxes

$$\text{Process Emissions} = \underset{\text{Production (tons/year)}}{(54 \times 10^6)} \; \underset{\text{Emission Factor (lb/ton)}}{(20)} \left(\frac{1}{2{,}000}\right) = 540{,}000 \text{ tons/year}$$

Application of Control = 100 %

Process Emissions into Uncontrolled Plants = 0 tons/year

Process Emissions into Controlled Plants = 540,000 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclone	40	216,000
Cyclone and ESP	40	216,000
Fabric filter	20	108,000

Table B-59. FINE-PARTICLE EMISSIONS FROM SINTER MACHINE WINDBOXES CONTROLLED BY CYCLONES

Process - Sinter machine windboxes

Control Device - Cyclones

Process Emissions into Control Device 216,000 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclones Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	32		3,456
1-3	2.7	57		3,324
0.5-1.0	0.56	82		992
0.1-0.5	0.24	94		487
0.05-0.1		100		0
0.01-0.05		100		0
Total	8.50			8,259

---

a/ Efficiency values were taken from high fractional efficiency curve.

Table B-60. FINE-PARTICLE EMISSIONS FROM SINTER MACHINE WINDBOXES CONTROLLED BY CYCLONES PLUS ELECTROSTATIC PRECIPITATORS

Process - Sinter machine windboxes

Control Device - Cyclone and ESP

Process Emissions into Control Device 216,000 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone[a] Penetration (%) (1 - efficiency)	Control Device ESP[b] Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	32	7	242
1-3	2.7	57	11	366
0.5-1.0	0.56	82	17	169
0.1-0.5	0.24	94	29	141
0.05-0.1		100	41	0
0.01-0.05		100	55	0
Total	8.50			918

---

a/ Efficiency valves were taken from high fractional efficiency curve.

b/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-61. FINE-PARTICLE EMISSIONS FROM SINTER MACHINE WINDBOXES CONTROLLED BY FABRIC FILTERS

Process - Sinter machine windboxes

Control Device - Fabric filter

Process Emissions into Control Device 108,000 tons/year

Process Emissions Size (μ)	Percent	Control Device Fabric filter Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	0.01		1
1-3	2.7	0.5		15
0.5-1.0	0.56	1.8		11
0.1-0.5	0.24	3.3		9
0.05-0.1		4.2		
0.01-0.05		4.4		
Total	8.50			36

Table B-62. SUMMARY OF FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS
(tons/year)

Source - Iron foundries

Process - Cupolas

Particle Size Range (µ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	Wet Scrubber	ESP	Fabric Filter	
3-7	5,610	377	79	8	0	6,074
1-3	5,178	516	761	11	4	6,466
0.5-1.0	1,726	201	520	6	5	2,458
0.1-0.5	1,985	240	1,028	12	10	3,275
0.05-0.1	302	36	201	3	2	544
0.01-0.05	302	36	211	3	2	554
Total Emissions	15,103	1,406	2,800	43	23	19,375

Table B-63. DISTRIBUTION OF PROCESS EMISSIONS FROM IRON FOUNDRY CUPOLAS

Source - Iron foundries

Process - Cupolas

Production[a] (tons/year) — Emission Factor[b] (lb/ton)

Process Emissions = (20.3×10^6) (17) $\left(\frac{1}{2,000}\right)$ = 172,600 tons/year

Application of Control = 50 %[c]

Process Emissions into Uncontrolled Plants = 86,300 tons/year

Process Emissions into Controlled Plants = 86,300 tons/year

Type of Control Device	% Application on[d] Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclone	12	10,356
Wet scrubber	70[e]	60,410
ESP	2	1,726
Fabric filter	16	13,808

---

[a] Based on 16.5×10^6 tons of gray and malleable iron castings shipped in 1972 (U.S. Industrial Outlook) and 73% of hot metal poured is shipped (A.T. Kearny PB-207 148) and 90% of production is from cupolas.

$$16.5 \times 10^6 \times \frac{90\%}{73\%} = 20.3 \times 10^6 \text{ tons of hot metal from cupolas}$$

[b] Reference 12.

[c] [d] Based on Particulate Pollutant System Study Volume I and trends indicated by A.T. Kearny in PB-207 148 and PB-198 348.

[e] Based on 32% wet caps and 38% wet scrubbers.

Table B-64. FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS

Process - Iron foundry cupolas

Control Device - Uncontrolled

Process Emissions into Control Device 86,300 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	6.5	100		5,610
1-3	6.0	100		5,178
0.5-1.0	2.0	100		1,726
0.1-0.5	2.3	100		1,985
0.05-0.1	0.35	100		302
0.01-0.05	0.35	100		302
Total	17.5			15,103

Table B-65. FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS CONTROLLED BY CYCLONES

Process - Iron foundry cupolas

Control Device - Cyclones

Process Emissions into Control Device 10,356 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclones Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	6.5	56		377
1-3	6.0	83		516
0.5-1.0	2.0	97		201
0.1-0.5	2.3	99		240
0.05-0.1	0.35	100		36
0.01-0.05	0.35	100		36
Total	17.50			1,406

---

[a] Efficiency values were taken from medium fractional efficiency curve.

Table B-66. FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS CONTROLLED BY WET SCRUBBERS

Process - Iron foundry cupolas

Control Device - Wet scrubbers

Process Emissions into Control Device 60,410 tons/year

Process Emissions Size (μ)	Percent	Control Device: Wet scrubber Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	6.5	2		79
1-3	6.0	21		761
0.5-1.0	2.0	43		520
0.1-0.5	2.3	74		1,028
0.05-0.1	0.35	95		201
0.01-0.05	0.35	100		211
Total				2,800

---

[a] Efficiency valves taken from medium fractional efficiency curve.

Table B-67. FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLAS CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Iron foundry cupola

Control Device - ESP

Process Emissions into Control Device 1,726 tons/year

Process Emissions Size (μ)	Percent	Control Device ESP Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	6.5	7		8
1-3	6.0	11		11
0.5-1.0	2.0	17		6
0.1-0.5	2.3	29		12
0.05-0.1	0.35	41		3
0.01-0.05	0.35	55		3
Total	17.50			43

---

a/ Efficiency values were taken from medium fractional efficiency curve.

Table B-68. FINE-PARTICLE EMISSIONS FROM IRON FOUNDRY CUPOLA CONTROLLED BY FABRIC FILTER

Process - Iron foundry cupola

Control Device - Fabric filter

Process Emissions into Control Device 13,808 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Fabric filter Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	6.5	0.01		0
1-3	6.0	0.5		4
0.5-1.0	2.0	1.8		5
0.1-0.5	2.3	3.3		10
0.05-0.1	0.35	4.2		2
0.01-0.05	0.35	4.4		2
Total	17.50			23

Table B-69. SUMMARY OF FINE-PARTICLE EMISSIONS FROM PULP MILL BARK-FIRED BOILERS
(tons/year)

Source - Pulp mills

Process - Bark-fired boilers

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclones				
3-7	6,070	53,251				59,321
1-3	4,198	54,590				58,788
0.5-1.0	910	13,836				14,746
0.1-0.5	435	6,884				7,319
0.05-0.1	15	238				253
0.01-0.05	5	79				84
Total Emissions	11,633	128,842				140,511

Table B-70. DISTRIBUTION OF PROCESS EMISSIONS FROM PULP MILL BARK-FIRED BOILERS

Source - Pulp mills

Process - Bark-fired boilers

Process Emissions = Production (tons/year)[a] ( ) Emission Factor[a] (lb/ton) ( ) $\left(\frac{1}{2,000}\right)$ = 843,000[a] tons/year

Application of Control = 94 %[b]

Process Emissions into Uncontrolled Plants = 50,580 tons/year

Process Emissions into Controlled Plants = 792,420 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclones	100	792,420

---

[a] Ratio of $\frac{\text{1972 pulp production}}{\text{1968 pulp production}}$ = 1.148

1968 process emissions were calculated as 734,400 tons/year in Particulate Pollutant System Study Volume I, p. 114. Therefore, 1972 processes emissions are estimated to be 734,400 x 1.148 = 843,000 tons/year

[b] Eighty percent of process emissions are produced in boilers with fly-ash reinjection. Twenty percent of process emissions are produced in boilers without fly-ash reinjection. One-hundred percent of boilers with fly-ash reinjection are controlled by cyclones. Seventy percent of boilers without fly-ash reinjection are controlled by cyclones.

Therefore, net application of control is (1.00 x 0.80 + 0.70 x 0.20) x 100 = 94%.

Table B-71. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED PULP MILL BARK-FIRED BOILERS

Process - Pulp mill bark-fired boilers

Control Device - Uncontrolled

Process Emissions into Control Device 50,580 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	12.0	100		6,070
1-3	8.3	100		4,198
0.5-1.0	1.8	100		910
0.1-0.5	0.86	100		435
0.05-0.1	0.03	100		15
0.01-0.05	0.01	100		5
Total	23.00			11,633

Table B-72. FINE-PARTICLE EMISSIONS FROM PULP MILL BARK-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Pulp mill bark fired boilers

Control Device - Cyclones

Process Emissions into Control Device 792,420 tons/year

Process Emissions		Control Device	Control Device	
		Cyclones		
Size (μ)	Percent	Penetration (%) (1 - efficiency) [a]	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	12.0	56		53,251
1-3	8.3	83		54,590
0.5-1.0	1.8	97		13,836
0.1-0.5	0.86	99		6,884
0.05-0.1	0.03	100		238
0.01-0.05	0.01	100		79
Total	23.00			128,842

---

[a] Efficiency values were taken from medium fractional efficiency curve.

Table B-73. SUMMARY OF FINE-PARTICLE EMISSIONS FROM KRAFT PULP MILL RECOVERY FURNACES
(tons/year)

Source - Kraft pulp mill

Process - Recovery furnaces

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP[a]				
3-7	3,533	24,486				28,019
1-3	10,365	112,871				123,236
0.5-1.0	5,653	95,147				100,800
0.1-0.5	3,251	93,328				96,579
0.05-0.1	45	1,817				1,862
0.01-0.05	2	128				130
Total Emissions	22,849	327,777				350,626

---

[a] Fractional efficiency characteristics of specialized Venturi evaporator systems which are also used are not known. Since electrostatic precipitator represents most applications, we will assume all are equivalent to "medium" efficiency electrostatic precipitators.

Table B-74. DISTRIBUTION OF PROCESS EMISSIONS FROM KRAFT PULP MILL RECOVERY FURNACES

Source - Kraft pulp mill

Process - Recovery furnaces

	Production (tons/year)	Emission Factor[a/] (lb/ton)		
Process Emissions =	(31.2×10^6)	(151)	$\left(\frac{1}{2,000}\right)$	=2,355,600 tons/year

Application of Control = 99 %

Process Emissions into Uncontrolled Plants = 23,556 tons/year

Process Emissions into Controlled Plants = 2,332,044 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	82	2,332,044[b/]
ESP and wet	4	
Venturi evaporator	11	
Venturi and wet	3	

[a/] Reference 12.

[b/] Fractional efficiency characteristics of these specialized venturi evaporator systems are not known. Since electrostatic precipitator represents most applications, we will assume all are equivalent to "medium" efficiency electrostatic precipitators.

Table B-75. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED KRAFT PULP MILL RECOVERY FURNACES

Process - Kraft pulp mill recovery furnace

Control Device - Uncontrolled

Process Emissions into Control Device 23,556 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	15	100		3,533
1-3	44	100		10,365
0.5-1.0	24	100		5,653
0.1-0.5	13.8	100		3,251
0.05-0.1	0.19	100		45
0.01-0.05	0.01	100		2
Total	97.00			22,849

Table B-76. FINE-PARTICLE EMISSIONS FROM KRAFT PULP MILL RECOVERY FURNACES CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Kraft pulp mill recovery furnaces

Control Device - Electrostatic precipitators

Process Emissions into Control Device 2,332,044 tons/year

Process Emissions Size (μ)	Percent	Control Device ESP a,b/ Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	15	7		24,486
1-3	44	11		112,871
0.5-1.0	24	17		95,147
0.1-0.5	13.8	29		93,328
0.05-0.1	0.19	41		1,817
0.01-0.05	0.01	55		128
Total	97.00			327,777

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

b/ Fractional efficiency characteristics of specialized Venturi evaporator systems which are also used are not known. Since electrostatic precipitator represents most applications, we will assume all are equivalent to "medium" efficiency electrostatic precipitators.

Table B-77. SUMMARY OF FINE-PARTICLE EMISSIONS FROM KRAFT PULP MILL LIME KILNS
(tons/year)

Source - Kraft pulp mills

Process - Lime kilns

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Scrubbers				
3-7	386	764				1,150
1-3	98	2,029				2,127
0.5-1.0	6	269				275
0.1-0.5	1	103				104
0.05-0.1	0	0				0
0.01-0.05	0	0				0
Total Emissions	491	3,165				3,656

Table B-78. DISTRIBUTION OF PROCESS EMISSIONS FROM KRAFT PULP MILL LIME KILNS

Source - Kraft pulp mills

Process - Lime kilns

$$\text{Process Emissions} = \underset{\text{(tons/year)}}{\overset{\text{Production}^{a/}}{(31.2 \times 10^6)}} \quad \underset{\text{(lb/ton)}}{\overset{\text{Emission Factor}^{b/}}{(45)}} \left(\frac{1}{2{,}000}\right) = 702{,}000 \text{ tons/year}$$

Application of Control = 99 %

Process Emissions into Uncontrolled Plants = 7,020 tons/year

Process Emissions into Controlled Plants = 694,980 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Wet scrubbers	100	694,980

---

a/ Production of kraft pulp.

b/ Emission factor is per ton of kraft pulp. Reference 12.

Table B-79. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED KRAFT PULP MILL LIME KILNS

Process - Kraft pulp mill lime kilns

Control Device - Uncontrolled

Process Emissions into Control Device 7,020 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.5	100		386
1-3	1.39	100		98
0.5-1.0	0.09	100		6
0.1-0.5	0.02	100		1
0.05-0.1	0	100		0
0.01-0.05	0	100		0
Total	7.00			491

Table B-80. FINE-PARTICLE EMISSIONS FROM KRAFT PULP MILL LIME KILNS CONTROLLED BY WET SCRUBBERS

Process - Kraft pulp mill lime kilns

Control Device - Wet scrubbers

Process Emissions into Control Device 694,980 tons/year

Process Emissions		Control Device Scrubbers a/	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.5	2		764
1-3	1.39	21		2,029
0.5-1.0	0.09	43		269
0.1-0.5	0.02	74		103
0.05-0.1	0	95		0
0.01-0.05	0	100		0
Total	7.00			3,165

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-81. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ROTARY LIME KILNS
(tons/year)

Source - Lime plant

Process - Rotary kiln

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	Wet Scrubber	Fabric Filter		
3-7	11,760	14,874	1,156	7		27,797
1-3	9,996	18,739	10,319	305		39,559
0.5-1.0	3,528	7,708	7,457	388		19,081
0.1-0.5	3,469	7,914	12,620	700		24,703
0.05-0.1	388	877	1,812	100		3,177
0.01-0.05	259	584	1,272	70		2,185
Total Emissions	29,400	50,696	34,636	1,570		116,502

Table B-82. DISTRIBUTION OF PROCESS EMISSIONS FROM ROTARY LIME KILNS

Source - Lime

Process - Rotary kiln

	Production [a] (tons/year)	Emission Factor [b] (lb/ton)		
Process Emissions =	(16.8×10^6)	(200)	$\left(\frac{1}{2,000}\right)$	= 1,680,000 tons/year

Application of Control = 93 % [c]

Process Emissions into Uncontrolled Plants = 117,600 tons/year

Process Emissions into Controlled Plants = 1,562,400 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclones	17	265,608
Wet	37	578,088
Fabric filter	46	718,704

---

[a] Mr. Kenneth A. Gutschick, Technical Service Manager, National Lime Association.

21.0×10^6 total lime production in 1972
13.5×10^6 commercial production
7.5×10^6 captive production
80% rotary kiln production; 20% vertical kiln production.

[b] Reference 12.

[c] }
[d] } Estimates based on 1968 phone survey and indicated trends.

	1968 Survey	1972 Estimate
Uncontrolled	13.0%	7.0%
Cyclone	17.9%	15.8%
Wet	30.8%	34.4%
Fabric filter	38.3%	42.8%

Table B-83. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ROTARY LIME KILNS

Process - Lime plant--rotary kilns

Control Device - Uncontrolled

Process Emissions into Control Device 117,600 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10.0	100		11,760
1-3	8.5	100		9,996
0.5-1.0	3.0	100		3,528
0.1-0.5	2.95	100		3,469
0.05-0.1	0.33	100		388
0.01-0.05	0.22	100		259
Total	25.00			29,400

Table B-84. FINE-PARTICLE EMISSIONS FROM ROTARY LIME KILNS CONTROLLED BY CYCLONES

Process - Lime plant--rotary kiln

Control Device - Cyclones

Process Emissions into Control Device 265,608 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device: Cyclone Penetration (%) (1 - efficiency)	Control Device: Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10.0	56		14,874
1-3	8.5	83		18,739
0.5-1.0	3.0	97		7,708
0.1-0.5	2.95	99		7,914
0.05-0.1	0.33	100		877
0.01-0.05	0.22	100		584
Total	25.00			50,696

Table B-85. FINE-PARTICLE EMISSIONS FROM ROTARY LIME KILNS CONTROLLED BY WET SCRUBBERS

Process - Lime plant--rotary kiln

Control Device - Wet scrubbers

Process Emissions into Control Device 578,088 tons/year

Process Emissions Size (μ)	Percent	Control Device Wet scrubber a/ Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10.0	2		1,156
1-3	8.5	21		10,319
0.5-1.0	3.0	43		7,457
0.1-0.5	2.95	74		12,620
0.05-0.1	0.33	95		1,812
0.01-0.05	0.22	100		1,272
Total	25.00			34,636

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-86. FINE-PARTICLE EMISSIONS FROM ROTARY LIME KILNS CONTROLLED BY FABRIC FILTERS

Process - Lime plant--rotary kiln

Control Device - Fabric filter

Process Emissions into Control Device 718,704 tons/year

Process Emissions		Control Device Fabric filter	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10.0	0.01		7
1-3	8.5	0.5		305
0.5-1.0	3.0	1.8		388
0.1-0.5	2.95	3.3		700
0.05-0.1	0.33	4.2		100
0.01-0.05	0.22	4.4		70
Total	25.00			1,570

Table B-87. SUMMARY OF FINE-PARTICLE EMISSIONS FROM LIME PLANT SECONDARY SOURCES
(tons/year)

Source - Lime plant

Process - Secondary sources

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Scrubber[a]				
3-7	22,176	1,774				23,950
1-3	24,255	20,374				44,629
0.5-1.0	3,119	5,364				8,483
0.1-0.5	346	1,026				1,372
0.05-0.1	0	0				0
0.01-0.05	0	0				0
Total Emissions	49,896	28,538				78,434

---

a/ See note d in Table B-88.

Table B-88. DISTRIBUTION OF PROCESS EMISSIONS FROM LIME PLANT SECONDARY SOURCES

Source - Lime plant

Process - Secondary sources

	Production[a] (tons/year)	Emission Factor [b] (lb/ton)		
Process Emissions =	(21×10^6)	(33)	$\left(\frac{1}{2,000}\right)$	= 346,500 tons/year

Application of Control = 80 %

Process Emissions into Uncontrolled Plants = 69,300 tons/year

Process Emissions into Controlled Plants = 277,200 tons/year

Type of Control Device	% Application on Controlled Plants[d]	Process Emissions Into Control Device (tons/year)[d]
Medium efficiency wet scrubber	100	277,200

---

[a] See note a in Table B-82.

[b] Reference 12.

[c] 1968 phone survey.

[d] Control devices vary from simple water sprays to fabric filters. Since note enough information was obtained for an accurate break-down all controlled plants were assumed to have medium efficiency wet scrubbers.

Table B-89. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED LIME PLANT SECONDARY SOURCES

Process - Lime plant--secondary sources

Control Device - Uncontrolled

Process Emissions into Control Device 69,300 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	32	100		22,176
1-3	35	100		24,255
0.5-1.0	4.5	100		3,119
0.1-0.5	0.5	100		346
0.05-0.1	0	100		0
0.01-0.05	0	100		0
Total	72.0			49,896

Table B-90. FINE-PARTICLE EMISSIONS FROM LIME PLANT SECONDARY SOURCES CONTROLLED BY WET SCRUBBERS[a]

Process - Lime plant secondary sources

Control Device - Wet scrubber[a]

Process Emissions into Control Device 277,200 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Wet scrubber[a] Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	32	2		1,774
1-3	35	21		20,374
0.5-1.0	4.5	43		5,364
0.1-0.5	0.5	74		1,026
0.05-0.1	0	95		0
0.01-0.05	0	100		0
Total	72.0			28,538

---

[a] See note a in Table B-88

Table B-91. SUMMARY OF FINE-PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS
(tons/year)

Source - Municipal incinerators

Process - Incineration

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	Cyclone	Scrubber[a]	Scrubber[b]	ESP	
3-7	3,564	405	543	14	25	4,551
1-3	5,346	900	2,524	228	60	9,058
0.5-1.0	2,495	491	2,317	218	43	5,564
0.1-0.5	3,208	658	4,200	482	94	8,642
0.05-0.1	713	145	1,075	137	30	2,100
0.01-0.05	1,069	217	1,628	217	60	3,191
Total Emissions	16,395	2,816	12,287	1,296	312	33,106

---

[a] Low efficiency.

[b] Medium efficiency.

Table B-92. DISTRIBUTION OF PROCESS EMISSIONS FROM MUNICIPAL INCINERATORS

Source - Municipal incinerators

Process - Incineration

$$\text{Process Emissions} = \underset{\text{(tons/year)}}{\overset{\text{Production}}{(18 \times 10^6)}} \quad \underset{\text{(lb/ton)}}{\overset{\text{Emission Factor}}{(24)}} \left(\frac{1}{2{,}000}\right) = 216{,}000 \text{ tons/year}$$

Application of Control = 67 %

Process Emissions into Uncontrolled Plants = 71,280 tons/year

Process Emissions into Controlled Plants = 144,720 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclone	10	14,472
Low efficiency scrubber	75	108,540
Medium efficiency scrubber	10	14,472
Electrostatic precipitator	5	7,236

Table B-93. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED MUNICIPAL INCINERATORS

Process - Municipal incinerators

Control Device - Uncontrolled

Process Emissions into Control Device 71,280 tons/year

Process Emissions		Control Device	Control Device	
		Uncontrolled		
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	100		3,564
1-3	7.5	100		5,346
0.5-1.0	3.5	100		2,495
0.1-0.5	4.5	100		3,208
0.05-0.1	1.0	100		713
0.01-0.05	1.5	100		1,069
Total	23.0			16,395

Table B-94. FINE-PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS CONTROLLED BY CYCLONES

Process - Municipal incinerators

Control Device - Cyclones

Process Emissions into Control Device 14,472 tons/year

Process Emissions Size (μ)	Percent	Control Device Cyclones a/ Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	56		405
1-3	7.5	83		900
0.5-1.0	3.5	97		491
0.1-0.5	4.5	99		658
0.05-0.1	1.0	100		145
0.01-0.05	1.5	100		217
Total	23.0			2,816

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-95. FINE-PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS CONTROLLED BY LOW EFFICIENCY SCRUBBERS

Process - Municipal incinerators

Control Device - Low efficiency scrubbers

Process Emissions into Control Device 108,540 tons/year

Process Emissions Size (μ)	Percent	Control Device Scrubber a/ Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	10		543
1-3	7.5	31		2,524
0.5-1.0	3.5	61		2,317
0.1-0.5	4.5	86		4,200
0.05-0.1	1.0	99		1,075
0.01-0.05	1.5	100		1,628
Total	23.0			12,287

---

a/ Efficiency valves were taken from low fractional efficiency curve.

Table B-96. FINE-PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS CONTROLLED BY MEDIUM EFFICIENCY SCRUBBERS

Process - Municipal incinerators

Control Device - Medium efficiency scrubbers

Process Emissions into Control Device 14,472 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Scrubber[a] Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	2		14
1-3	7.5	21		228
0.5-1.0	3.5	43		218
0.1-0.5	4.5	74		482
0.05-0.1	1.0	95		137
0.01-0.05	1.5	100		217
Total	23.0			1,296

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-97. FINE-PARTICLE EMISSIONS FROM MUNICIPAL INCINERATORS CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Municipal incinerators

Control Device - Electrostatic precipitators

Process Emissions into Control Device 7,236 tons/year

Process Emissions Size (μ)	Percent	Control Device ESP[a/] Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5.0	7		25
1-3	7.5	11		60
0.5-1.0	3.5	17		43
0.1-0.5	4.5	29		94
0.05-0.1	1.0	41		30
0.01-0.05	1.5	55		60
Total	23.0			312

---

a/ Efficiency valves were taken from medium fractional efficiency curve.

Table B-98. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS
(tons/year)

Source - Stationary combustion

Process - Electric utility pulverized coal-fired boiler

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP	Cyclone	Cyclone and ESP	FF	
3-7	137,600	181,440	332,288	14,443	None	665,771
1-3	86,000	178,200	369,930	25,268		659,398
0.5-1.0	18,060	57,834	111,758	11,797		199,449
0.1-0.5	7,482	40,873	53,075	9,558		110,988
0.05-0.1	172	1,328	1,298	330		3,128
0.01-0.05						
Total Emissions	249,314	459,675	868,349	61,396		1,638,734

Table B-99. DISTRIBUTION OF PROCESS EMISSIONS FROM ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS

Source - Stationary combustion

Process - Electric utility coal-fired boiler

	Production (tons/year)	Emission Factor (lb/ton)		
Process Emissions =	(290.6×10^6)	(190)	$\left(\frac{1}{2,000}\right)$	$= 27.6 \times 10^6$ tons/year

Application of Control = 96.9 %

Process Emissions into Uncontrolled Plants = 0.86×10^6 tons/year

Process Emissions into Controlled Plants = 26.7×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
Cyclones	24.3	6.59×10^6
Cyclones and ESP	15.1	4.03×10^6
ESP	60.6	16.2×10^6

Table B-100. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS

Process - Electric utility pulverized coal-fired boilers

Control Device - Uncontrolled

Process Emissions into Control Device 0.86×10^6 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16	100		137,600
1-3	10	100		86,000
0.5-1.0	2.1	100		18,060
0.1-0.5	0.87	100		7,482
0.05-0.1	0.02	100		172
0.01-0.05				
Total				249,314

Table B-101. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Electriç utility pulverized coal-fired boiler

Control Devicc - Electrostatic precipitator

Process Emissions into Control Device 16.2 x 10^6 tons/year

Process Emissions		Control Device ESP	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency) a/	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16	7		181,440
1-3	10	11		178,200
0.5-1.0	2.1	17		57,834
0.1-0.5	0.87	29		40,873
0.05-0.1	0.02	41		1,328
0.01-0.05				
Total				459,675

---

a/ Efficiency values used were taken from medium efficiency fractional efficiency curve.

Table B-102. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Electric utility pulverized coal-fired boiler

Control Device - Cyclone

Process Emissions into Control Device 6.49×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%) (1 - efficiency)[a]	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16	32		332,288
1-3	10	57		369,930
0.5-1.0	2.1	82		111,758
0.1-0.5	0.87	94		53,075
0.05-0.1	0.02	100		1,298
0.01-0.05				
Total				868,349

---

[a] Efficiency values used were taken from high efficiency cyclone curve because power plants use higher efficiency units.

Table B-103. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY PULVERIZED COAL-FIRED BOILERS CONTROLLED BY CYCLONE PLUS ELECTROSTATIC PRECIPITATOR

Process - Electric utility pulverized coal-fired boilers

Control Device - Cyclone and ESP

Process Emissions into Control Device 4.03×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%) (1 - efficiency)	Control Device ESP Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	16	32	7	14,443
1-3	10	57	11	25,268
0.5-1.0	2.1	82	17	11,797
0.1-0.5	0.87	94	29	9,558
0.05-0.1	0.02	100	41	330
0.01-0.05				
Total				61,396

Table B-104. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY STOKER COAL-FIRED BOILERS (tons/year)

Source - Stationary combustion

Process - Electric utility stoker coal-fired boiler

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
	Uncontrolled	Controlled				
		ESP	Cyclone	Cyclone and ESP	FF	
3-7	18,720	457	38,131	None		57,308
1-3	4,992	191	18,112			23,295
0.5-1.0	936	56	4,886			5,878
0.1-0.5	302	31	1,805			2,138
0.05-0.1						
0.01-0.05						
Total Emissions	24,950	735	62,934			88,619

Table B-105. DISTRIBUTION OF PROCESS EMISSIONS FROM ELECTRIC UTILITY STOKER COAL-FIRED BOILER

Source - Stationary combustion

Process - Electric utility stoker coal-fired boiler

	Production (tons/year)	Emission Factor (lb/ton)		
Process Emissions =	(11.02×10^6)	(146)	$\left(\frac{1}{2,000}\right)$	= 0.804×10^6 tons/year

Application of Control = 87 %

Process Emissions into Uncontrolled Plants = 0.104×10^6 tons/year

Process Emissions into Controlled Plants = 0.699×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	5.2	0.0363×10^6
Cyclone	94.8	0.662×10^6

Table B-106. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ELECTRIC UTILITY STOKER COAL-FIRED BOILERS

Process - Electric utility stoker coal-fired boiler

Control Device - Uncontrolled

Process Emissions into Control Device 0.104×10^6 tons/year

Process Emissions Size (μ)	Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	18	100		18,720
1-3	4.8	100		4,992
0.5-1.0	0.9	100		936
0.1-0.5	0.29	100		302
0.05-0.1				
0.01-0.05				
Total				24,950

Table B-107. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY STOKER COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATORS

Process - Electric utility stoker coal-fired boiler

Control Device - ESP

Process Emissions into Control Device 0.0363 x 10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device ESP Penetration (%) a/ (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	18	7		457
1-3	4.8	11		191
0.5-1.0	0.9	17		56
0.1-0.5	0.29	29		31
0.05-0.1				
0.01-0.05				
Total				735

---

a/ Efficiency value taken from medium efficiency curve.

Table B-108. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY STOKER COAL-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Electric utility stoker coal-fired boiler

Control Device - Cyclone

Process Emissions into Control Device 0.662×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%) a/ (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	18	32		38,131
1-3	4.8	57		18,112
0.5-1.0	0.9	82		4,886
0.1-0.5	0.29	94		1,805
0.05-0.1				
0.01-0.05				
Total				62,934

---

a/ Efficiency values used were taken from high efficiency cyclone curve because power plants use higher efficiency units.

Table B-109. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY CYCLONE COAL-FIRED BOILERS (tons/year)

Source - Stationary combustion

Process - Electric utility cyclone coal-fired boilers

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
	Uncontrolled	Controlled				
		ESP	Cyclone	Cyclone and ESP	FF	
3-7	41,250	5,758	6,080			53,088
1-3	36,300	7,962	9,530			53,792
0.5-1.0	9,075	3,203	3,428			15,706
0.1-0.5	4,026	2,328	1,743			8,097
0.05-0.1	100	67	38			205
0.01-0.05						
Total Emissions	90,751	19,318	20,819			130,888

Table B-110. DISTRIBUTION OF PROCESS EMISSIONS FROM ELECTRIC UTILITY CYCLONE COAL-FIRED BOILERS

Source - Stationary combustion

Process - Electric utility cyclone coal-fired boiler

	Production (tons/year)	Emission Factor (lb/ton)		
Process Emissions =	(32.3×10^6)	(35)	$\left(\frac{1}{2{,}000}\right)$	$= 0.57 \times 10^6$ tons/year

Application of Control = 71 %

Process Emissions into Uncontrolled Plants = 0.165×10^6 tons/year

Process Emissions into Controlled Plants = 0.405×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	81.2	0.329×10^6
Cyclone	18.8	0.076×10^6

Table B-111. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED ELECTRIC UTILITY CYCLONE COAL-FIRED BOILERS

Process - Electric utility coal-fired boiler

Control Device - Uncontrolled

Process Emissions into Control Device 0.165×10^6 tons/year

Process Emissions		Control Device Uncontrolled	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	25	100		41,250
1-3	22	100		36,300
0.5-1.0	5.5	100		9,075
0.1-0.5	2.44	100		4,026
0.05-0.1	0.05	100		100
0.01-0.05				
Total				90,751

Table B-112. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY CYCLONE COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Electric utility cyclone coal-fired boiler

Control Device - ESP

Process Emissions into Control Device 0.329 x 10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device ESP Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	25	7		5,758
1-3	22	11		7,962
0.5-1.0	5.5	17		3,203
0.1-0.5	2.44	29		2,328
0.05-0.1	0.05	41		67
0.01-0.05				
Total				19,318

---

[a] Efficiency values used were taken from medium fractional efficiency curve.

Table B-113. FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY CYCLONE COAL-FIRED BOILERS CONTROLLED BY CYCLONE

Process - Electric utility cyclone coal-fired boiler

Control Device - Cyclone

Process Emissions into Control Device 0.076×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	25	32		6,080
1-3	22	57		9,530
0.5-1.0	5.5	82		3,428
0.1-0.5	2.44	94		1,743
0.05-0.1	0.05	100		38
0.01-0.05				
Total				20,819

---

[a] Efficiency values were taken from high efficiency cyclone curve.

Table B-114. SUMMARY OF FINE-PARTICLE EMISSIONS FROM INDUSTRIAL PULVERIZED COAL-FIRED BOILERS
(tons/year)

Source - Stationary combustion

Process - Industrial pulverized coal-fired boilers

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP	Cyclone	Cyclone and ESP	FF	
3-7	11,000	5,180	52,800	None	None	68,980
1-3	2,145	1,587	18,340			22,072
0.5-1.0	55	63	677			795
0.1-0.5						
0.05-0.1						
0.01-0.05						
Total Emissions	13,200	6,830	71,817			91,847

Table B-115. DISTRIBUTION OF PROCESS EMISSIONS FROM INDUSTRIAL PULVERIZED COAL-FIRED BOILERS

Source - Stationary combustion

Process - Industrial pulverized coal-fired boiler

	Production (tons/year)	Emission Factor (lb/ton)		
Process Emissions =	(29.84×10^6)	(170)	$\left(\frac{1}{2,000}\right)$	= 2.5×10^6 tons/year

Application of Control = 95.5 %

Process Emissions into Uncontrolled Plants = 0.11×10^6 tons/year

Process Emissions into Controlled Plants = 2.39×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	31	0.74×10^6
Cyclone	69	1.65×10^6

Table B-116. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED INDUSTRIAL PULVERIZED COAL-FIRED BOILERS

Process - Industrial pulverized coal-fired boiler

Control Device - Uncontrolled

Process Emissions into Control Device 0.11×10^6 tons/year

Process Emissions		Control Device Uncontrolled	Control Device	
Size (μ)	Percent	Penetration (%) (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10	100		11,000
1-3	1.95	100		2,145
0.5-1.0	0.05	100		55
0.1-0.5				
0.05-0.1				
0.01-0.05				
Total				13,200

Table B-117. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL PULVERIZED COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Industrial pulverized coal-fired boiler

Control Device - ESP

Process Emissions into Control Device 0.74×10^6 tons/year

Process Emissions		Control Device ESP	Control Device	
Size (μ)	Percent	Penetration (%)[a] (1 - efficiency)	Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10	7		5,180
1-3	1.95	11		1,587
0.5-1.0	0.05	17		63
0.1-0.5				
0.05-0.1				
0.01-0.05				
Total				6,830

---

[a] Efficiency values used were taken from medium fractional efficiency curve.

Table B-118. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL PULVERIZED COAL-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Industrial pulverized coal-fired boiler

Control Device - Cyclones

Process Emissions into Control Device 1.65×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%) (1 - efficiency) a/	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	10	32		52,800
1-3	1.95	57		18,340
0.5-1.0	0.05	82		677
0.1-0.5				
0.05-0.1				
0.01-0.05				
Total				71,817

---

a/ Efficiency values used were taken from high efficiency cyclone curve.

Table B-119. SUMMARY OF FINE-PARTICLE EMISSIONS FROM INDUSTRIAL STOKER COAL-FIRED BOILERS (tons/year)

Source - Stationary combustion

Process - Industrial stoker coal-fired boilers

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled	ESP	Cyclone	Cyclone and ESP	FF	
3-7	132,000	2,240	58,720			192,960
1-3	46,464	1,239	36,817			84,520
0.5-1.0	5,016	207	5,718			10,941
0.1-0.5	1,320	93	1,725			3,138
0.05-0.1						
0.01-0.05						
Total Emissions	184,800	3,779	102,980			291,559

Table B-120. DISTRIBUTION OF PROCESS EMISSIONS FROM INDUSTRIAL STOKER COAL-FIRED BOILERS

Source - Stationary conbustion

Process - Industrial stoker coal-fired boilers

Process Emissions = Production (tons/year) (104.44) Emission Factor (lb/ton) (133) $\left(\frac{1}{2,000}\right)$ = 6.95×10^6 tons/year

Application of Control = 62 %

Process Emissions into Uncontrolled Plants = 2.64×10^6 tons/year

Process Emissions into Controlled Plants = 4.31×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	14.8	0.64×10^6
Cyclone	85.2	3.67×10^6

Table B-121. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED INDUSTRIAL STOKER COAL-FIRED BOILERS

Process - Industrial stoker coal-fired boiler

Control Device - Uncontrolled

Process Emissions into Control Device 2.64×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5	100		132,000
1-3	1.76	100		46,464
0.5-1.0	0.19	100		5,016
0.1-0.5	0.05	100		1,320
0.05-0.1				
0.01-0.05				
Total				184,800

Table B-122. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL STOKER COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Industrial stoker coal-fired boiler

Control Device - ESP

Process Emissions into Control Device 0.64×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device ESP Penetration (%) [a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5	7		2,240
1-3	1.76	11		1,239
0.5-1.0	0.19	17		207
0.1-0.5	0.05	29		93
0.05-0.1				
0.01-0.05				
Total				3,779

---

[a] Efficiency values were taken from medium fractional efficiency curve.

Table B-123. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL STOKER COAL-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Industrial stoker coal-fired boiler

Control Device - Cyclone

Process Emissions into Control Device 3.67×10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Cyclone Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	5	32		58,720
1-3	1.76	57		36,817
0.5-1.0	0.19	82		5,718
0.1-0.5	0.05	94		1,725
0.05-0.1				
0.01-0.05				
Total				102,980

---

[a] Efficiency values were taken from high efficiency cyclone curve.

Table B-124. SUMMARY OF FINE-PARTICLE EMISSIONS FROM INDUSTRIAL CYCLONE COAL-FIRED BOILERS
(tons/year)

Source - Stationary combustion

Process - Industrial cyclone coal-fired boiler

	Distribution of Emissions					
		Controlled				
Particle Size Range (μ)	Uncontrolled	ESP	Cyclone	Cyclone and ESP	FF	Total Emissions
3-7	4,140	1,610	6,016			11,766
1-3	4,761	2,910	12,323			19,994
0.5-1.0	1,760	1,662	6,552			9,974
0.1-0.5	890	1,434	3,800			6,124
0.05-0.1	33	75	150			258
0.01-0.05	8	25	38			71
Total Emissions	11,592	7,716	28,879			48,187

Table B-125. DISTRIBUTION OF PROCESS EMISSIONS FROM INDUSTRIAL CYCLONE COAL-FIRED BOILERS

Source - Stationary combustion

Process - Industrial cyclone coal-fired boiler

	Production (tons/year)	Emission Factor (lb/ton)		
Process Emissions =	(14.92×10^6)	(31)	$\left(\frac{1}{2,000}\right)$	$= 0.23 \times 10^6$ tons/year

Application of Control = 91 %

Process Emissions into Uncontrolled Plants = 0.0207×10^6 tons/year

Process Emissions into Controlled Plants = 0.209×10^6 tons/year

Type of Control Device	% Application on Controlled Plants	Process Emissions Into Control Device (tons/year)
ESP	55	0.115×10^6
Cyclone	45	0.094×10^6

Table B-126. FINE-PARTICLE EMISSIONS FROM UNCONTROLLED INDUSTRIAL CYCLONE COAL-FIRED BOILERS

Process - Industrial cyclone coal-fired boiler

Control Device - Uncontrolled

Process Emissions into Control Device 0.0207 x 10^6 tons/year

Process Emissions Size (μ)	Process Emissions Percent	Control Device Uncontrolled Penetration (%) (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	20	100		4,140
1-3	23	100		4,761
0.5-1.0	8.5	100		1,760
0.1-0.5	4.3	100		890
0.05-0.1	0.16	100		33
0.01-0.05	0.04	100		8
Total				11,592

Table B-127. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL CYCLONE COAL-FIRED BOILERS CONTROLLED BY ELECTROSTATIC PRECIPITATOR

Process - Industrial cyclone coal-fired boiler

Control Device - ESP

Process Emissions into Control Device 0.115×10^6 tons/year

Process Emissions Size (µ)	Process Emissions Percent	Control Device ESP Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	20	7		1,610
1-3	23	11		2,910
0.5-1.0	8.5	17		1,662
0.1-0.5	4.3	29		1,434
0.05-0.1	0.16	41		75
0.01-0.05	0.04	55		25
Total				7,716

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[a] Efficiency values were taken from medium fractional efficiency curve.

Table B-128. FINE-PARTICLE EMISSIONS FROM INDUSTRIAL CYCLONE COAL-FIRED BOILERS CONTROLLED BY CYCLONES

Process - Industrial cyclone coal-fired boiler

Control Device - Cyclones

Process Emissions into Control Device 0.094 x 10^6 tons/year

Process Emissions Size (μ)	Percent	Control Device Cyclones Penetration (%)[a] (1 - efficiency)	Control Device Penetration (%) (1 - efficiency)	Emissions (tons/year)
3-7	20	32		6,016
1-3	23	57		12,323
0.5-1.0	8.5	82		6,552
0.1-0.5	4.3	94		3,800
0.05-0.1	0.16	100		150
0.01-0.05	0.04	100		38
Total				28,879

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[a] Efficiency values were taken from high efficiency curve.

Table B-129. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY AND INDUSTRIAL OIL-FIRED BOILERS
(tons/year)

Source - Stationary combustion

Process - Electric utility and industrial oil-fired boiler

	Distribution of Emissions					
		Controlled				
Particle Size Range (μ)	Uncontrolled					Total Emissions
3-7	190,665[a]					190,665
1-3						
0.5-1.0						
0.1-0.5						
0.05-0.1						
0.01-0.05						
Total Emissions						190,665

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[a] No accurate particle size or net control data available, assumed that process emissions are 90% < 7 μm and all plants uncontrolled.

Table B-130. SUMMARY OF FINE-PARTICLE EMISSIONS FROM ELECTRIC UTILITY AND INDUSTRIAL GAS-FIRED BOILERS
(tons/year)

Source - Stationary combustion

Process - Electric utility and industrial gas and LPG-fired boilers

Particle Size Range (μ)	Distribution of Emissions					Total Emissions
		Controlled				
	Uncontrolled					
3-7	104,895[a]					104,895
1-3						
0.5-1.0						
0.1-0.5						
0.05-0.1						
0.01-0.05						
Total Emissions						104,895

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a/ No accurate particle size or net control data; assumed that process emissions are 90% < 3 μm and all plants uncontrolled.